Sunrises at Stonehenge

In the Stonehenge planetarium show, your class begins learning about the patterns of change in sunrises that have been repeating in yearly cycles for aeons past and will continue in yearly cycles for aeons to come. The builders of Stonehenge were attuned to these cycles as were most cultures throughout history until, perhaps, our own, when the move to great cities and the use of artificial lighting have made solar motion less visible and less crucial for our daily lives. In this activity, your students perform a detailed study of the yearly cycle of sunrises. According to Gerald Hawkins and his followers, the giant stones of Stonehenge mark the solstice extremes in this cycle.

Materials

For each student:

- 1 Sunrise Table and Chart for the year 2000 (master on page 3)
- 1 pencil
- Optional: a colored pen or pencil.

Before Class

1. Photocopy each of the above sheets for each student.
2. Separate the tables from the charts using a paper cutter.

In Class

1. Let's pretend that we are near Stonehenge in Southern England. We have a clear view of the horizon and can watch the Sun rise every day of the year.

   If the students have already seen the Stonehenge planetarium program, ask them to recall what they learned about how the position of sunrise changes throughout the year:

   What's the longest day of the year? [About June 21, the Summer Solstice.]

   On the Summer Solstice, does the Sun rise to the north or the south of East? [The Sun rises to the north of East in the summer.]

   What's the shortest day of the year? [About December 21, the Winter Solstice.]

   On the Winter Solstice, does the Sun rise to the north or south of East? [The Sun rises to the south of East in the winter.]

2. We are going to make a chart that will show how the sunrise positions change throughout the year.

   Hand out a blank sunrise chart to each student. (Do not hand out the tables yet.) Point out the words "Azimuth of Sunrise" along the bottom. Review concepts from "Azimuth and Horizons" classroom activity:

   What does azimuth mean? [Azimuth means the direction in degrees, as marked on a compass.]

   What is the azimuth of North? [0°.] East? [90°.] South? [180°.]

   If the Sun were to rise exactly in the Northeast (halfway between North and East), what would the azimuth of sunrise be? [45°.]

3. How far to the North will the Sun rise on the Summer Solstice, as seen from Stonehenge?

   Ask a few students to share their guesses with the rest of the class. Then, show the students how to indicate their guesses on the chart. Find the month of June along the left, and the azimuth of the guess on

the chart. Place a pencil dot in the box that indicates both the month of June and azimuth of sunrise. For example, if they think that the builders of Stonehenge will see sunrise exactly in the Northeast on June 21, they should put a dot in the box to the right of June, and above 45°.

4. Place a pencil dot showing the azimuth of sunrise for each of these four important dates:

   Summer Solstice, about June 21

   Winter Solstice, about December 21

   Spring Equinox, about March 21

   Fall Equinox, about September 21

5. Use your pencils to join the four pencil dots with a smooth curve, showing how you think the sunrise point will change between the four important dates.

   Invite them to share their predictions with their neighbors. Invite some of the students to share their predictions with the whole class.

6. Here is a Table of Sunrise positions at Stonehenge.

   Hand out the Table of Sunrise Positions at Stonehenge.

The table shows the actual azimuth of sunrise as we would see it if we made observations at Stonehenge today.

Use a colored pencil or pen to plot each position on your chart with an "x," and then to use the pen to connect the x's with a smooth line.

7. Compare your paper with your neighbors'.

   Check that they have all plotted the positions of sunrise correctly. Lead a discussion to help the students interpret their results.

How close did your predictions come to the actual observations?

How far to the North did the Sun rise on the Summer Solstice? How far to the South did it rise on the Winter Solstice? Is that more or less than you predicted? {Summer 49°, Winter 128°.]

When does the Sun rise due East? [On September 21 and March 21.]

Do you think the Sun goes through the same pattern every year? If so, how do we know? [Ancient peoples around the world saw the same pattern of the Sun every year that we still see today!]

The exact dates of solstices and equinoxes changes from year to year, but are always within a day or two of March 21, June 21, September 21, and December 21. This is because the length of the calendar year (365 days) is not exactly the same as the solar year 365.26 days—this is also why we need leap year. For example, in the year 2000, the Summer Solstice occurs on June 20, and the Winter Solstice on December 21. You may wish to add that modern measurements indicate that even the azimuth angles change very slightly over the centuries because of slight changes in the tilt of the Earth's axis with respect to its orbit.

Table of Sunrise Positions at Stonehenge in the Year 2000

Latitude: 51°17' N

Date	Time	Position	Date	Time	Position	Date	Time	Position
01/20	8:03 am	122°	05/20	4:11 am	55°	09/20	5:54 am	87°
02/20	7:14 am	106°	06/20	3:53 am	49°	10/20	6:43 am	106°
03/20	6:11 am	88°	07/20	4:18 am	54°	11/20	7:36 am	121°
04/20	5:03 am	69°	08/20	5:05 am	69°	12/20	8:12 am	128°

Chart of Sunrise Positions (Year: _____ Latitude:_____)

		0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
Jan																				
Feb																				
Mar																				
Apr																				
May																				
Jun																				
Jul																				
Aug																				
Sep																				
Oct																				
Nov																				
Dec																				
	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	

(North) (East) (South)

Azimuth of Sunrise

Going Further

1. It is very interesting to explore more precisely the day to day change in the azimuth of sunrise. For this purpose, the table below shows the azimuth of sunrise on two or more successive days for each month of the year. Make a copy of the table for each student. Explain that these tables are more precise because the azimuths are given with degrees *and* minutes (minutes indicated by the symbol " ' "). There are 60 minutes in each degree. After the students have studied the table for a while, ask:

   During which months does azimuth of sunrise change the most from one day to the next? [March and September.] During which months does the azimuth of sunrise change the least? [June and December.] What are the exact dates of the solstices for the year 2000? [December 21 and June 20.]

2. Instead of handing out the sunrise tables, have the students create their own, using a computer with astronomical "planetarium" software that can compute precise sunrise positions. For example, the data compiled in the sunrise table on the previous page was generated by the *Voyager* program (from Carina Software, 830 Williams St., San Leandro, CA 94577; 510-352-7328) for Macintosh computers. An appropriate program for IBM-compatible computers is *AstroInfo*, which gives daily Sun and Moon risings and settings, with azimuth angles. It is available from Zephyr Services, 1900 Murray Ave., Dept. A, Pittsburgh, PA 15217; phone 800-533-6666. *NIGHTSKY*, also for IBM-compatibles, is a similar program to *Voyager* in that it produces star charts as well as tables. It is available from Southwest Astronomy, 4242 Roma NE, Albuquerque, NM 87108. *NS Lito* (a simple version of *NIGHTSKY*) is available as freeware on computer services such as Compuserve.

3. Make a similar sunrise position chart for another year to verify that it is essentially the same shape.

4. The latitude of Stonehenge is 51°17' N. Use a computer program to generate a table of sunrise positions for the latitude of your school.

More Sunrise Positions at Stonehenge in the Year 2000

Latitude: 51°17' N

Date	Time	Position	Date	Time	Position	Date	Time	Position
01/20	8:03 am	122°09′	06/19	3:53 am	49°06′	09/22	5:57 am	88°56′
01/21	8:03 am	121°46′	06/20	3:53 am	49°03′	09/23	5:58 am	89°27′
02/20	7:14 am	106°40′	06/21	3:54 am	49°06′	09/24	6:00 am	90°09′
02/21	7:12 am	106°05′	06/22	3:54 am	49°07′	10/20	6:43 am	106°02′
03/18	6:16 am	90°05′	06/23	3:54 am	49°08′	10/21	6:45 am	106°41′
03/19	6:13 am	89°19′	06/24	3:55 am	49°18′	11/20	7:36 am	121°37′
03/20	6:11 am	88°45′	07/20	4:18 am	54°34′	11/21	7:38 am	122°04′
04/20	5:03 am	69°57′	07/21	4:19 am	54°52′	12/19	8:11 am	128°07′
04/21	5:01 am	69°24′	08/20	5:05 am	69°10′	12/20	8:12 am	128°13′
05/20	4:11 am	55°22′	08/21	5:06 am	69°37′	12/21	8:12 am	128°14′
05/21	4:10 am	55°03′	09/20	5:54 am	87°43′	12/22	8:13 am	128°13′
06/18	3:53 am	49°09′	09/21	5:55 am	88°14′	12/23	8:13 am	128°07′
						12/24	8:13 am	128°00′