Chapter 2: Measuring the Earth with a Meter Stick

Student Worksheet

Objective: To make a measurement of the circumference of the Earth, using little more than a meter stick and a telephone, nearly reenacting the measurement done by Eratosthenes around 230 BCE.

Engage: Brainstorm a way to measure your school's campus without any tools and without leaving the room. Describe your process and state your estimate.

Introduction: In astronomy it is difficult to imagine how celestial objects are measured. How do we know how massive and distant the stars are? How do we measure the Earth? The question "how?" is perhaps the most important one. Humans have had a good measurement for the circumference of the Earth for over 2,000 years. The unit of measure for the calculation done by the Greek, Eratosthenes, was the stadia, the length of a typical stadium, or about 600 ft.

In this activity you will recreate the measurement of the Earth as done by Eratosthenes near the year 230 BCE. Recall that Eratosthenes noticed that on the summer solstice the sun shone directly into a well in Syene (modern day Aswan in southern Egypt). On that same day he knew that in Alexandria the shadow of a vertical pole was 7 degrees 2 arc minutes. This lends an image like the following in Figure 1 below:

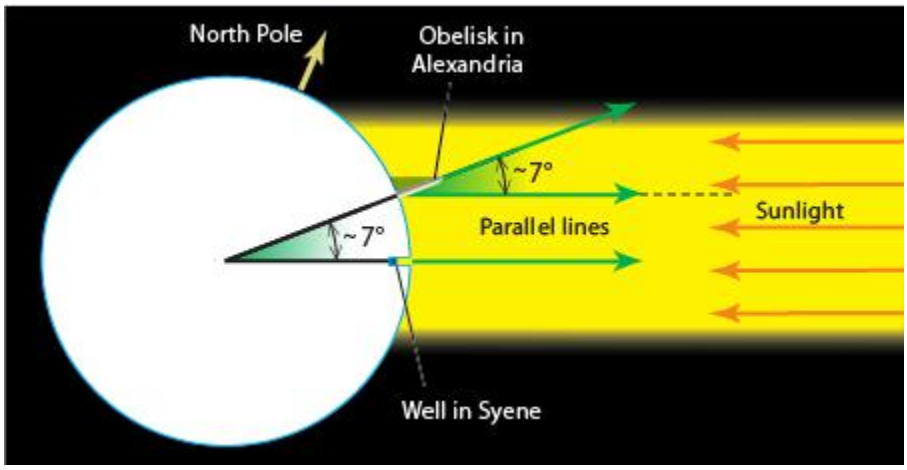

Figure 1 Eratosthenes's calculation of the circumference of the earth

The A denotes Alexandria. The S denotes Syene. The angle formed from the stick in Alexandria is equal to the angle with a vertex at the Earth's center that meets Alexandria and Syene. The Greeks knew that a circle has 360 degrees. The angle of 7 degrees meant

the distance between Alexandria to Syene was 7/360^{ths} or about 1/50th of Earth's circumference.

Your Task: Re-create the experiment. Verify your results.

Procedure:

1. Find your local noon. It differs based on your exact location and daylight savings time. A great source for this is the US Naval Observatory website.
2. Go outside to a sunny location. Plant a stick in the ground near the time of local noon.
3. Measure the length of the shadow.
4. Measure the length of the stick.
5. Call a friend far to the north or south of you, (at least a hundred miles away). At their local noon they should plant a stick in the ground and measure its length and shadow as you have done. Get the data from your friend.
6. Use a road atlas and a ruler to determine the straight-line distance between your city and your friend's city.
7. On a piece of paper make a careful scale drawing of your shadow and your friend's shadow. A sample is shown below in Figure 2(a):

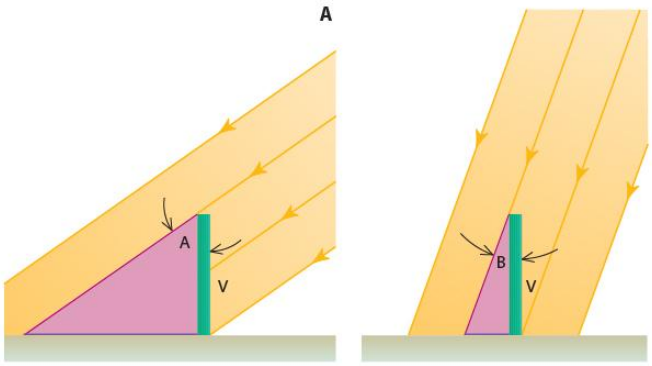

Figure 2(a)

8. From your drawing, measure the angles A and B at the top of the triangles.
9. Study the diagram in Figure 2(b) below.

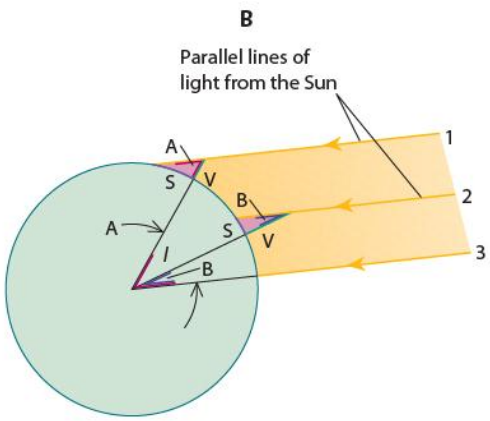

Figure 2(b)

Lines 1, 2, and 3 represent rays of the sun's light hitting Earth. Lines 1 and 2 meet the top of the sticks, while line 3 points toward the center of the Earth.

10. The angle AB equals the latitude between the two points on Earth. The difference in latitude is equal to angle A minus angle B--or l = A-B. This difference in latitude is the key to determining the circumference of the Earth.
11. 360 degrees divided by the latitude equals the circumference divided by d--or 360/l = C/d
12. Solve for C. You have now made a measurement of the circumference of the Earth.

Conclusion:

1. How might you conduct the experiment more accurately?

2. What step(s) of the procedure would not be available to Eratosthenes? How would he overcome this challenge?

3. Why is it necessary to measure the shadows at local noon?

4. How would your shadow measurements change if measuring in December? In May?

5. How would your shadow measurements change if measured closer to the North Pole? Closer to the equator?

6. Compare your circumference to the accepted value of the circumference of the Earth: 40,096 kilometers (24,901 miles). Calculate the percent error.

$$\% \text{ error} = \frac{\text{your value- accepted value}}{\text{accepted value}}$$

Extend:

- The unit of length used by Eratosthenes was the stadia, roughly the length of a stadium. Study the history of this unit of length as it appears in different cultures.

- How did humans learn the distance to the Moon?

- Simply recording the length of a stick's shadow made many early calendars. Sketch how the shadow would change throughout the year.

- How long would it take to walk the circumference of the Earth? Show your work.