Eratosthenes

or How to Measure Something That's Too Big to Measure Directly, or How to Measure the Earth's Circumference with the Help of Another School

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Purpose

Students will find the circumference of a wheel (or globe) directly and indirectly, and compare their results. Students will cooperate on the internet with a school (or schools) in another location to measure the circumference of the Earth.

The Greek philosopher, Eratosthenes, made an excellent estimate of the circumference of the Earth around 330 B.C. Eratosthenes assumed that the Earth is a sphere and that the sun's rays are parallel when they reach the earth. At the time of Eratosthenes, and for hundreds of years after, scholars believed that Eratosthenes' result was too large.

Materials

- Wheel ~25 cm diameter (or small globe that can be halved)
- Ruler
- Protractor
- Paper and pencil

Directions

1. First Method:
   a. Placing the wheel (or globe) with the center on the paper near one edge, draw the outline of the circle on the paper, marking the center.
   b. Draw a radius line from the center mark to the outside of the circle and ~3 cm beyond. This line represents a building standing perpendicular to the horizon at that point on the circle.
   c. Draw a second radius line from the center of the circle to another part of the circle. This line can represent a well that is perpendicular to the horizon at another point on the circle.
   d. Use the protractor to measure the angle (a) between the two radius lines.
   e. Use the ruler to measure the distance (s) along the circle between the two lines.
   f. Use the formula for circumference (C) of the Earth Science Reference Tables, \( s / C = a / 360^\circ \), rewritten as \( C = 360^\circ / (s \times a) \), to calculate the circumference of the wheel.
   g. Link to illustration of Eratosthenes' method.

2. Second Method:
a. Use the ruler to measure the diameter (d) of the wheel (or globe).
b. Use the formula $C=\pi d$ to calculate the circumference of the wheel.

3. Third Method: Use a tape measure wrapped around the wheel (or globe) to find the circumference.

4. Fourth Method:
   a. Place a meter stick on a table. Mark on point on the outside of the wheel (or globe) with chalk.
   b. Placing the wheel (or globe) next to the meter stick with the mark at 0cm, roll the wheel along the meter stick until you arrive at the marked spot.
   c. Read the value on the meter stick at that spot.

5. Internet project to find circumference of the Earth
   a. On the internet, join the Noon Observation Project, which will collect data in March, 1997. Contact ksmith@ncsa.uiuc.edu.
   b. Link to help compute local noon at your school. You also need to find the latitude and possibly the longitude of your school.
   c. If you choose to cooperate with another school at some other time of the year, try this link, which gives you a format to calculate the circumference of the earth collaborating with another school, which you must find.

Summary

1. Compare your values for all four measurements/calculations.
2. Using the result of your second method as the true value and the result of your first method as your experimental value, find the percent error using the formula in the Earth Science Reference Tables.

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   \% \text{ error} = \frac{\text{your value} - \text{[accepted value]} \times 100}{\text{accepted value}}.\]

3. Why would Eratosthenes' method not work if the earth were flat?
4. Why is it important that we assume that the Sun's rays arrive in parallel on the Earth?
5. How would your calculated circumference change if you measured the angle larger than it really is?
6. How would your calculated circumference change if you measured the angle smaller than it really is?
7. If you have calculated the circumference of the Earth via the internet, calculate your percent error. What could account for errors in your value? Evaluate your methods and brainstorm ideas for improving your results.
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