Measure the Ea

A summer solstice experiment

This may sound unbelievable, but you can measure the circumference of the Earth using an ordinary ruler. How? First, learn a brilliant measuring technique invented over two millennia ago. Then you can perform this amazing experiment in just a few minutes. It's easy, and it really works. But there's just one catch. It will only work on a few special days each year!

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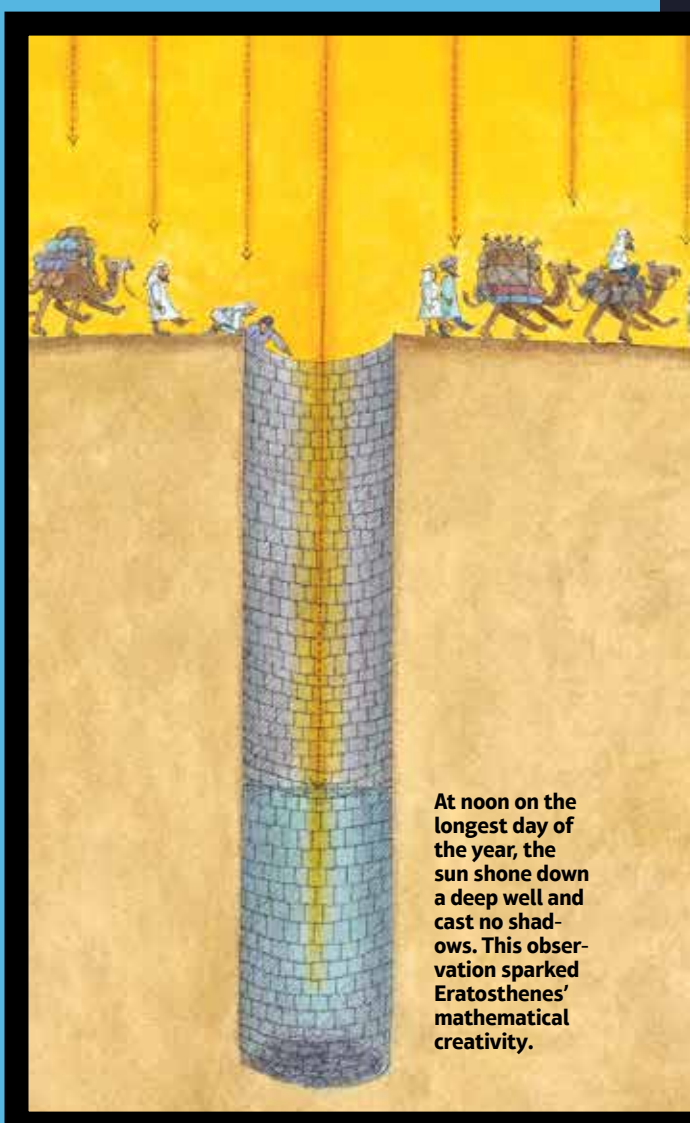
Circumference is the distance around the Earth at its widest point.

Eratosthenes and the Remarkable Story

Eratosthenes (276–194 BC) was a brilliant librarian in Alexandria, Egypt. Though we sometimes think that everyone once believed the world was flat, educated people in his day already knew the Earth was round. However, no one knew how big the Earth was.

According to legend, Eratosthenes heard a story that changed everything: far from his home, on one special day each year, there was a well where the sun cast no shadows at noon. The well was in a town called Syene. The day was the summer solstice.

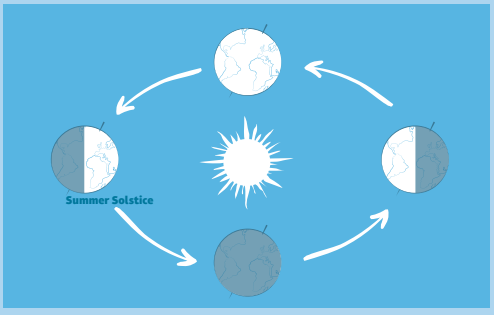
This tale must have seemed very strange to Eratosthenes, since the sun always cast shadows where he lived. That gave him a remarkable idea.



At noon on the longest day of the year, the sun shone down a deep well and cast no shadows. This observation sparked Eratosthenes' mathematical creativity.

What's Special About the Summer Solstice?

»**The summer solstice** marks the longest daylight of the year in the northern hemisphere, and the midday sun stands highest in the sky. This happens because on that day, Earth's axis leans most directly toward the sun.



Using the Story to Measure the Earth

First, Eratosthenes drew a diagram. It showed Earth as a circle and the sun's ray as parallel lines. His simple picture looks like one you might draw in geometry class. (No surprise, since the Greeks also invented geometry.)

Eratosthenes realized that on the solstice, this diagram would let him measure a "slice" of the Earth. All he needed to do was find the angle of the noon sun in Alexandria and determine determine the distance to the well in Syene. Once he did that, he could calculate the size of the entire Earth.

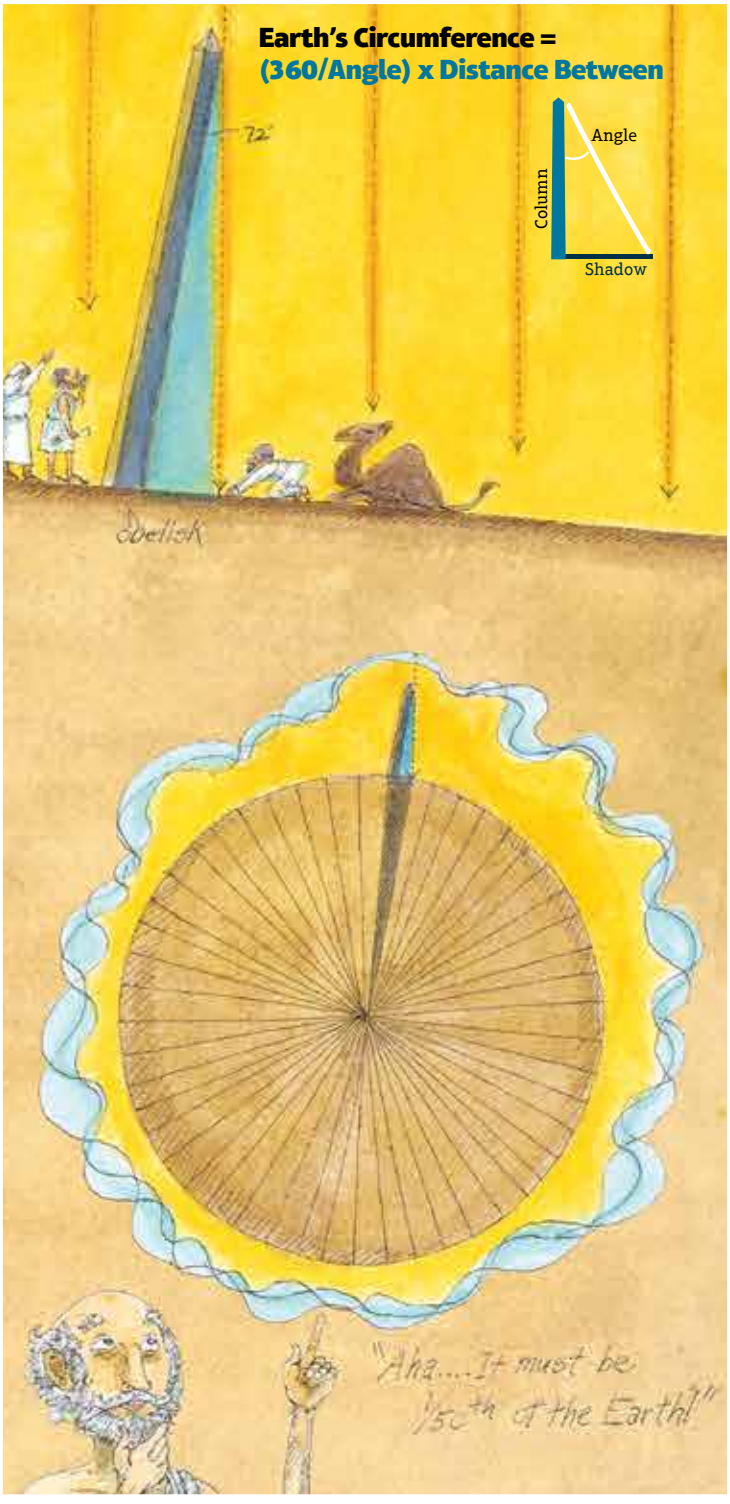
Getting the angle was easy for a math geek like Eratosthenes: just measure the shadow cast by a tall, upright column (called an obelisk) at noon. The height of the column and the length of the shadow form two sides of a triangle. He used a type of math called trigonometry to figure out the angle formed by the slanted side of the triangle. But measuring the exact distance to the well was really tough! At the time, people often estimated distances by timing how fast camel caravans traveled from one place to another. But camels can be stubborn. (Slowing down! Going the wrong way!) Legend has it that Eratosthenes paid measuring experts to walk the distance while counting their paces. The distance was about 500 miles (805 kilometers).

Totally Worth the Effort

Using his strategy, Eratosthenes calculated the circumference of Earth as 252,000 stadia (an ancient unit of measure equal to the length of a stadium). Converted to modern measurements, that is about 24,662 miles (39,590 kilometers)—astonishingly close to the circumference of 24,901 miles (40,075 kilometers) that we measure today. Some scholars say his number wasn't quite so accurate. Since ancient stadiums varied in length, it's difficult to convert his numbers into miles. But everyone agrees that Eratosthenes' calculation was an incredible feat of measurement.

But What If I Miss the Summer Solstice?

»**If you forget to measure on the solstice,** or if that day turns out cloudy, rainy, or not safe to measure where you live, try again at solar noon a day or two later. The experiment will still work.



Now You Can Do It Too

Are you ready? Because this may be the "biggest" science activity that you ever try at home! Here's how you can duplicate Eratosthenes' experiment.

YOU'LL NEED:

- **Ruler**
- **Protractor**
- **Pencil**
- **Large sheet of paper**
- **Watch**

But Wait . . . for the Summer Solstice

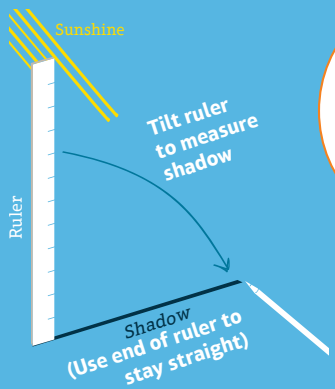
This experiment works only when our planet is perfectly aligned to the incoming sunshine. The solstice date varies each year from June 20 to 22. In 2016, it occurs on June 20th. The sun stands highest in the sky around noon. But the exact time varies depending on your location. Search online for the exact time of "solar noon" in your city. That's when to make your measurement.

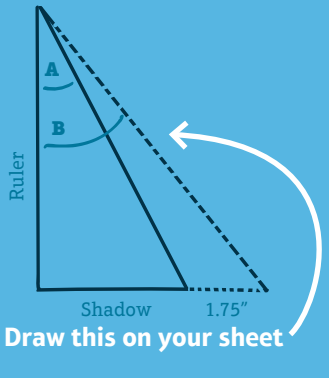
Find a safe, flat, level place where you will be able to see a shadow. A patio, playground, or picnic table would be great. Also remember basic safety: never look directly at the sun.

Time to Measure

Here's how to find the sun's angle at solar noon.

1. Hold your ruler straight up on the flat surface. While holding the ruler, lay your pencil's point exactly at the end of the ruler's shadow.
2. Now tilt your ruler down and use it to measure the shadow. Write down your answer.
3. Now it's time to draw your diagram. First, draw a vertical line the same length as the ruler.
4. Next, draw the horizontal line as long as the length of the shadow that you measured.
5. Connect the two lines to make a right triangle.
6. Use the protractor to measure the angle of the top corner of the triangle. This is Angle A.





Draw this on your sheet

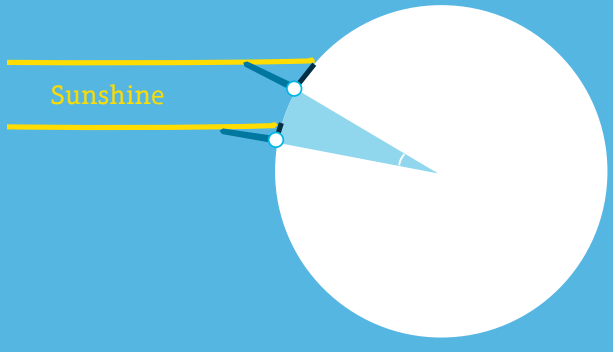
Using the Formula

Wait—what about that well? Eratosthenes compared shadows at his home and at a well 500 miles away. But you might not know how far you live from that well. (And you probably don't have a camel to measure the distance either.)

Don't worry, we have a back-up plan. On the solstice, if you live in the United States, traveling 500 miles due north would lengthen the shadow from your ruler by about 1.75 inches. So just add 1.75 inches to the shadow line in your diagram. Then draw a new diagonal line to the top of the triangle. Measure this new angle with your protractor. This is Angle B.

Now put both angles you've measured into the formula (360/[Angle B - Angle A]) x Distance Between. The "distance between" is 500 miles. Your answer will be your estimate for the circumference of the Earth.

Earth's Circumference =
(360/[Angle B - Angle A]) x Distance Between



You Rule(d) the Earth!

Congratulations, you've just done something **amazing!**

Of course, like any experiment, this one is subject to error. A tiny tilt in your ruler can vary your result. Time and other factors can vary it too.

Still, if you got the right number of digits in your answer (what mathematicians call "the right order of magnitude"), you can be really proud. We don't know how many times Eratosthenes tried this before he got his best result. So mark your calendar for next year's solstice, when we can all try this experiment again!

Nick D'Alto is working on a website to crowdsource measurements of Earth's circumference taken by people around the world.

What did you get?

Send your measurements (shadow length and Earth circumference) and your town or city to muse@cricketmedia.com. We'll gather everyone's results to get an even better measure of Earth. (P.S. If you live outside the U.S., email muse@cricketmedia.com before the solstice for special instructions.)