Stories of Science: The Size of the Earth

The story about how an ancient Egyptian calculated the size of the Earth with a stick.

The was once a time when our small planet seemed immense, when it was the only world we could explore. It's true size was first worked out in a simple and ingenious way by a man who live in Egypt in the third century B.C. In Alexandria at that time there lived a man named Eratosthenes. One of his envious contempories called him beta (the second letter of the greek alphabet) because Eratosthenes was second best in the world at everything, but it seems clear that in many fields Eratosthenes was alpha. He was an astronomer, historian, geographer, philosopher, poet, theatre critic and mathmetician. He was also the chief librarian at the great library of Alexandria and one day while reading a papyrus book in the library he came across a curious account.

Sun Cast No Shadows

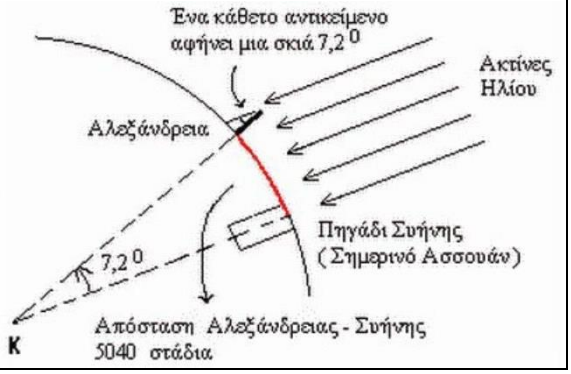
Far to the south, he read, at the frontier outpost of Seyene something notable could be seen on the longest day of the year. On June 21st the shadows of a temple column or vertical stick would grow shorter as noon approached and as the hours crept towards midday the sun's rays would slither down the sides of a deep well which on other days would remain in shadow. Then at precisely noon, the columns would cast no shadows and the sun would shine directly down into the water of the well. At that moment the sun was exactly overhead. It was an observation that someone else might easily have ignored - sticks, shadows, reflections in wells, the position of the sun – simple everyday matters of what possible importance might they be? But Eratosthenes was a scientist and his contemplation of these homely matters changed the world, in a way, made the world. Because Eratosthenes has the presence of mind to experiment, to actually ask whether back in Alexandria did a stick cast a shadow near noon on June 21st? And it turns out, sticks do.

A Curious Mind and A Simple Experiment

An overly skeptical person might have said that the report from Seyene was an error – but it's an absolutely straight forward observation – why would anyone lie on such a trivial matter? Eratosthenes asked himself how it could be that at the same moment a stick in Seyene would cast no shadow and a stick in Alexandria, 800km to the north would cast a very definite shadow? On the left is a map of ancient Eygpt with two sticks or Obelisks one in Alexandria and one down here in Seyene, now if at a certain moment each stick casts no shadow at all that is perfectly easy to understand, provided the Earth is flat, if the shadow at Seyene is a certain length and the shadow at Alexandria is the same length then that also makes sense on a flat Earth. But how could it be, Eratosthenes asked, that at the same instant there was no shadow at Seyene and a very substantial shadow at Alexandria? The answer was that the surface of the Earth is curved. Not only that, but that the greater the curvature, the greater the difference in the lengths of the shadows.

Simple Trigonometry

The sun is so far away that the rays are parallel when they reach the Earth. Sticks at different angles to the sun's rays will cast shadows of different lengths. For the observed difference in these shadow lengths the distance between Alexandria and Syene had to be about 7° along the surface of the Earth. By that I mean image the sticks extending all the way down to the centre of the earth they would there intersect at an angle of about 7°. Well 7° is something like 1/50th of the full circumference of the Earth (360°). Eratosthenes knew the distance between Alexandria and Seyene – he knew it was 800km – why? Because he hired a man to pace out the entire distance so that he could perform the calculation we're talking about. Now 800km x 50 is 40,000km so that must be the circumference of the Earth. That's how far it is to go once around the Earth. That's the right answer! Eratosthenes' only tools were sticks, eyes, feet and brains plus a zest for experiment. With those tools he correctly deduced the circumference of the earth to high precision with an error of only a few percent. That's pretty good figuring for 2200 years ago!



Comprehension and Reflection Questions

1. Suggest why Eratosthenes, one of greatest minds of his generation was working at a library?

.....

.....

.....

.....

2. Eratosthenes was not worried about the accuracy of the accounts from Seyene, what could he have done to check the veracity of these reports?

.....

.....

.....

.....

3.The circumference of the Earth is actually 40,075km. Calculate the actual error of Eratosthenes calculation of 40,000km

.....

.....

.....

.....

.....

Extension Activities

Ideas for things to do next:

The Earth isn't actually Spherical. Research "Polar Flattening" write about how much the poles are flattened at what caused it.

The definition of the "metre" was originally one ten millionth of the distance from the equator to the north pole. Research how this definition changed and find out what is used to define the exact distance of one meter today.

Further Reading

Ideas for things to read next:
Read about the great library at Alexandria
https://en.wikipedia.org/wiki/Library_of_Alexandria