

Rambam and the Size of the Sun

By: YORAM BOGACZ

The feat of measuring the size of the Earth was first accomplished by Eratosthenes, born around 276 B.C.E. in Cyrene, in modern-day Libya. For many years, Eratosthenes was the chief librarian at Alexandria, possibly the most prestigious academic post of the ancient world. Eratosthenes had learned of a well situated near the town of Syene in Southern Egypt, close to modern-day Aswan. At noon around 21st June each year (the summer solstice), the Sun was directly overhead and shone straight into the well. In Alexandria, several hundred kilometres to the north, this never happened. Eratosthenes thought that he could exploit this fact to measure the circumference of the Earth.

Figure 1 shows how parallel rays of light from the Sun hit the Earth at noon on 21st June. At noon—the same moment that some of the rays were plunging into the well at Syene—Eratosthenes stuck a stick vertically in the ground at Alexandria and measured the angle between the Sun's rays and the stick. This angle is equal to the angle between two lines drawn from Alexandria and Syene to the centre of the Earth. He measured the angle to be 7.2°.

Eratosthenes took the Earth to be perfectly spherical.¹ So if the angle between Syene and Alexandria is 7.2°, then the distance between the two cities represents $\frac{7.2}{360}$ of Earth's circumference, because there are 360 degrees in a full circle. So the distance between the two cities represents one-fiftieth of the circumference of the Earth [$\frac{7.2}{360} = 0.02 = \frac{1}{50}$].

The next step was to measure the distance between the two towns. It is not clear how Eratosthenes did this. One suggestion is that he measured the circumference of a cart wheel, and recorded the number of revolutions made by the wheel on the journey between Alexandria and Syene. The distance turned out to be 5,000 stades. Since this represents $\frac{1}{50}$ of the Earth's circumference, the total circumference must be 250,000 stades.

¹ This is correct to a first approximation. The Earth is actually an oblate spheroid, meaning that it bulges slightly at the equator, due to its rotation around its axis. So the equatorial radius is 6378 km, while the polar radius is 6356 km.

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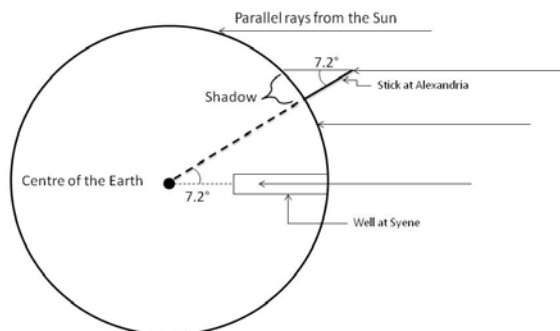


Figure 1. Eratosthenes used the shadow cast by a stick at Alexandria to calculate the circumference of the Earth. He concluded the experiment on the day of the summer solstice, where the noon Sun is directly above the Tropic of Cancer. Diagram is not to scale.

How far is 250,000 stades? The stade was a standard distance over which races were held. The Egyptian stade (as opposed to the Olympic stade) was 157 metres, which gives a circumference of 39,250 km. The modern figure is 40,075 km, a difference of just 2%. There were several inaccuracies in the method used by Eratosthenes. For example, Syene is not directly south of Alexandria. Furthermore, it is situated not precisely on the Tropic of Cancer, but slightly north of it (see Map 1). Nonetheless, given the tools at his disposal, Eratosthenes obtained a result of astonishing accuracy.



Map 1. Alexandria (top left) is on the shore of the Mediterranean Sea. The modern city of Aswan, close to the ancient Syene, is just north of Lake Nasser (bottom right). Notice that Aswan is not directly south of Alexandria; nor is it on the Tropic of Cancer.

The next step was to deduce the size of the Moon and Sun. The groundwork had been laid by earlier thinkers, but the calculations were incomplete until the size of the Earth had been established. Eratosthenes