FLAT EARTH

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How do we know that our earth is not flat? What kind of evidence do we have? Can children 'know' this through their own observations or through simple inexpensive experiments?

For a long time, the prevailing notion in some cultures was of our earth being a flat disk (see **Box 1**). The farthest one could see along the ground with the unaided eye (the horizon) was its boundary (see **Fig. 1**).

We no longer believe in such a view (see **Box 2**). For most of us, the earth is spherical, a simple fact that we have learnt as children (see **Box 3**). We have also seen numerous photographs taken from different vantage points in space that conclusively establish this fact (see **Fig. 2**). But, for a moment, let us forget the sphere we have seen in these photographs. What experiments or observations would help us conclude that our earth is not flat?

Objects vanishing beyond the horizon

If you are out on a beach or at any place where you have a wide view of water, observe a boat or ship sailing away. If the earth were flat, the boat or the ship would drop out of view abruptly when it reached the horizon. Instead, you will notice that the lower part of the boat disappears first, while the mast or flag will be the last to go out of view (see **Fig. 3a-b**). This happens because the earth is not flat. Its curvature causes parts of the ship closest to the ground to be blocked from our view first.

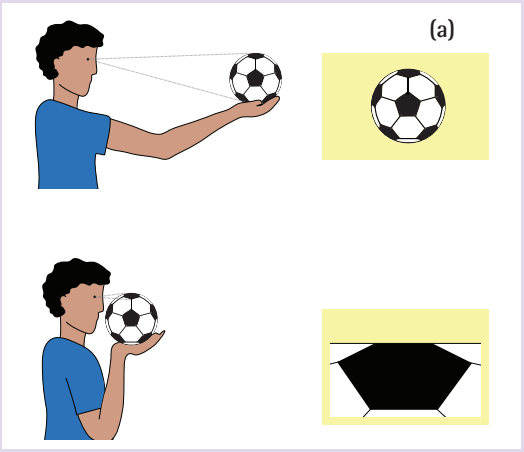
Objects on the horizon

Again, the next time you are out on a beach, compare what you can see of the setting sun when you are standing up with what you can see lying down. If the earth were flat, your view of the sun would be the same from both positions. However, you will notice that you can see more of the setting sun standing up than lying down. It is because the earth is curved like the surface of a sphere that the observer's height determines the

Box 1. Why did our earth appear flat?

Take a ball and keep your eye at the same level as its surface. From this viewing angle, the surface of the ball is likely to appear flat (see **Fig. 1a**). Now, imagine an ant moving on the surface of a fully blown-up balloon. For the ant, it would be difficult to comprehend that the surface on which it is moving about is not flat (see **Fig. 1b**).

This is exactly the case with us on Earth. The difficulty in accepting that the earth is round is that it 'appears' flat to us. But, as these examples show, something that appears flat need not be so. The earth curves everywhere. But the earth is also so big relative to us that the degree of curvature of its surface (the extent to which the earth curves away from a plane) is small and barely noticeable from where we stand. The curvature of the earth becomes apparent to us only from great heights, such as the top of a very tall building or while flying in an airplane.



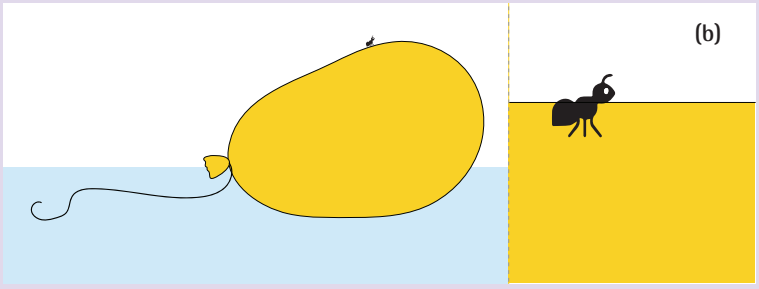


Fig. 1. A spherical object, like a ball or a balloon, may 'appear' flat from a certain viewing angle.

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Box 2. Aryabhata's spherical earth:

Aryabhata, an Indian mathematician-astronomer, described the earth as a sphere in the text *Aryabhatiyam*, written over 1500 years ago. In the *Gitikapada* portion of the text (verse 5), he shares the diameter of the earth in *yojana,* an ancient unit for distance. Combined with Aryabhata's own estimation of the value of the mathematical constant **π**, one can arrive at the circumference of the earth as well. Unfortunately, it has been difficult to compare these estimations with modern estimations largely because there is no consensus among scholars on what a *yojana* is in the units for distance we use today. Nonetheless, it is a fact that even during Aryabhata's time, the earth was known to be a sphere.

Aryabhata was also the first to propose the idea that the earth spins on its own axis and that the 'rising' and 'setting' of the objects that we see in the sky are relative to the earth's rotation. We leave it as an open exercise for the reader to figure out what observations one could do to check if the earth is indeed spinning. It is another one of those conclusions that seem contradictory to our everyday perception of reality and, therefore, not that easy to arrive at!

Box 3. The earth is NOT a perfect sphere:

As it turns out, our earth is not a perfect sphere either. Instead, its shape is that of an oblate spheroid, which means that it is slightly flattened at the poles and bulged at the equator, like a ball squished from two opposite sides. This shape is a result of the earth's rotation, which causes the equatorial regions to experience a centrifugal force that pushes material outward and causes the earth to bulge.

Fig. 2. The first full photo of the earth that showed that it was not flat. Known as 'The Blue Marble' this photo was taken on 7th December 1972, by the American crew of the Apollo 17 spacecraft.

Credits: Harrison Schmitt or Ron Evans. URL: https://en.wikipedia.org/wiki/File:The_Earth_seen_from_Apollo_17.jpg. License: Copyright NASA.

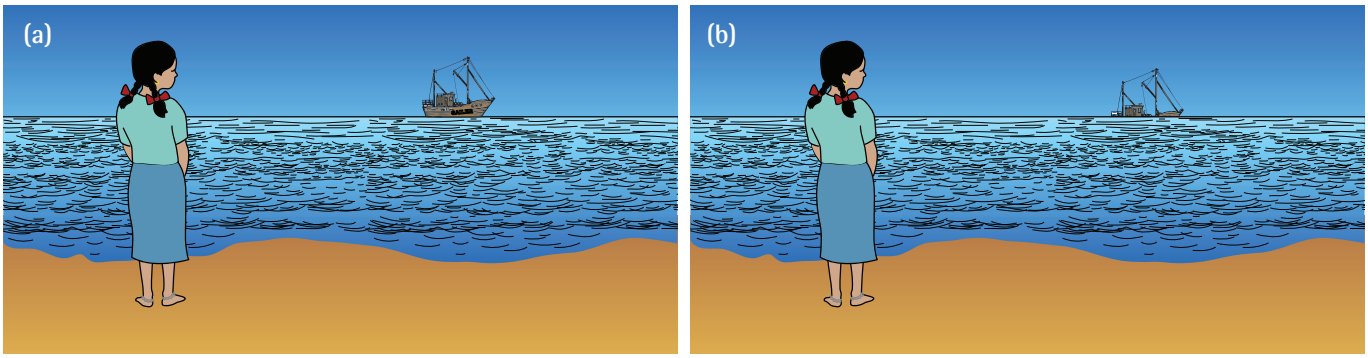


Fig. 3. Ships sailing away from land disappear gradually from our sight.

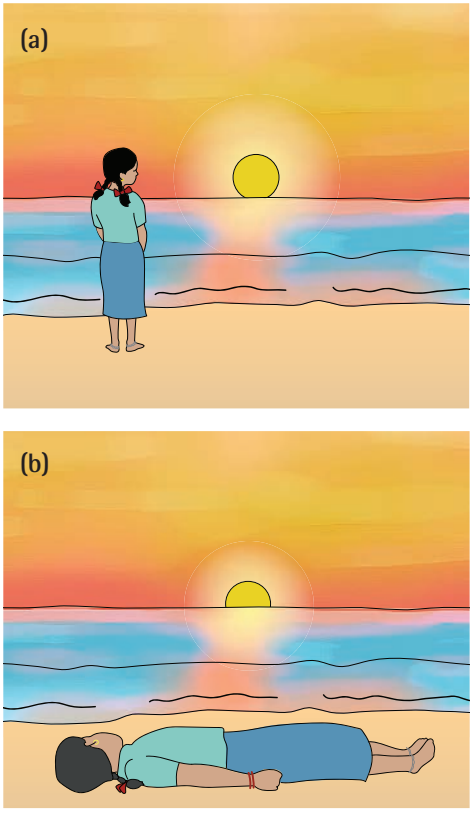


Fig. 4. We can see more of the setting sun standing up than lying down.

distance along the surface up to which they can see (see **Fig. 4a-b**).

You can also do this by standing in an open field and observing an object along the horizon, such as a far-distant tree or a building that is partially visible. As you climb to a higher vantage point, such as a nearby tree, you will be able to see more of the same object. You may even be able to see beyond it at other objects that were not visible to you before. Again, if the earth were flat, you would see no difference in the distance of your line of sight whether you were standing at the base or sitting on the branch of a tree. It is because the earth is curved that your line of sight extends further into the horizon the higher you climb. In other words, parts of the earth that were previously hidden by its curvature will now become visible due to the change in your vantage point (see **Fig. 5a-b**).

Length of shadows

Would the flatness or roundness of the earth change the length of our shadows? This can be tested by a simple experiment that can be done indoors. Take a spherical object like a ball or a fruit like an orange. Insert two toothpicks of equal length into it in such a way that they are about an inch apart (see **Fig. 6a**). Keeping the room dark, use a torch to shine a light on the ball and observe the length of the shadows of the toothpicks (see **Fig. 6b**). No matter what angle you choose to shine the light from, the shadows will not be of equal length (see **Fig. 6c**). In this experiment, the light source represents the sun and the ball represents the earth.

If you were to replace the ball with a flat surface, like a piece of thermocol, and repeat the same experiment, you will find the shadows to be of the same length (see **Fig. 7**).

One can repeat the same experiment at the scale of the earth if one were

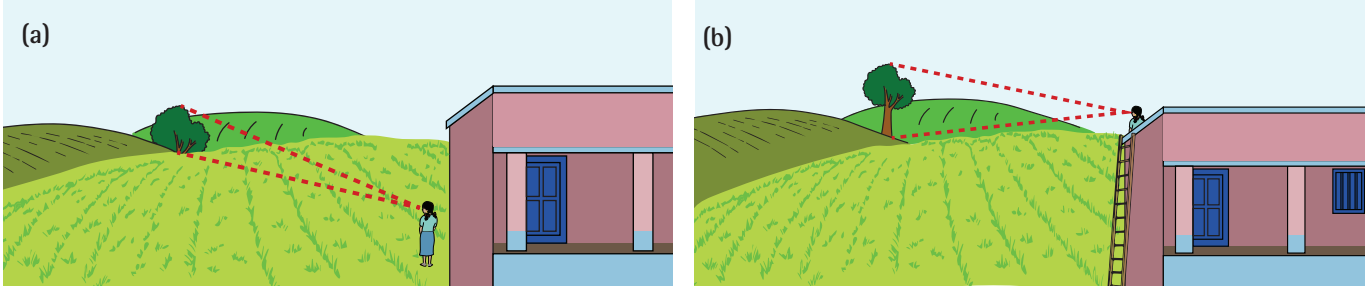
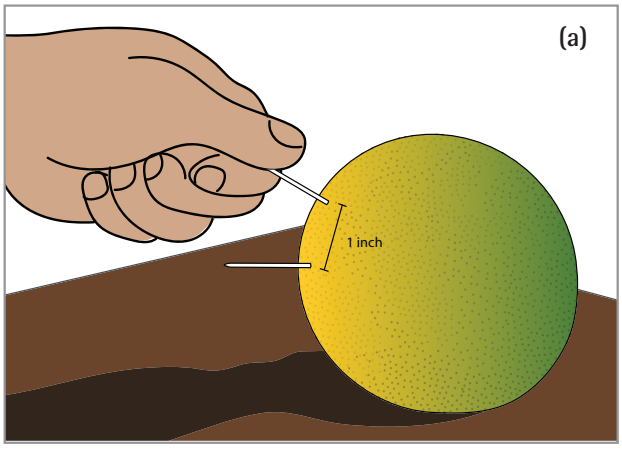


Fig. 5. The line of our sight extends further into the horizon the higher the position of observation.

to observe the shadows of two poles of identical heights that are several kilometres apart. The length of the shadows will have to be measured at approximately the same time. Interestingly, such a measurement was carried out by the Greek mathematician Eratosthenes more than 2000 years ago (see **Box 4**).



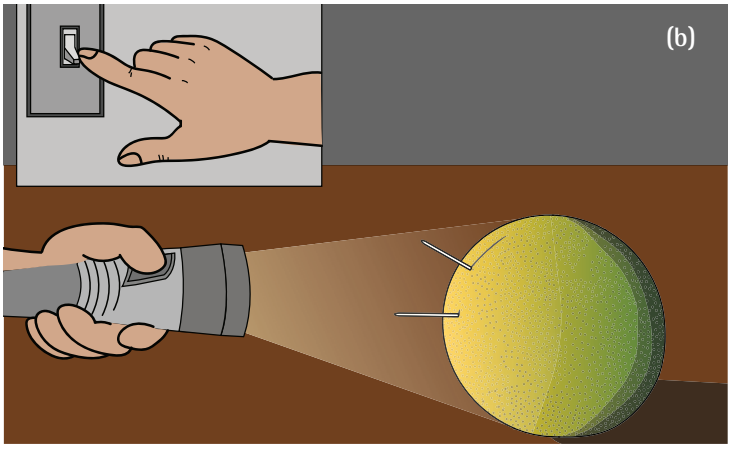


Fig. 6. When two objects of equal length stand on a curved surface, the shadows they cast are of unequal length.

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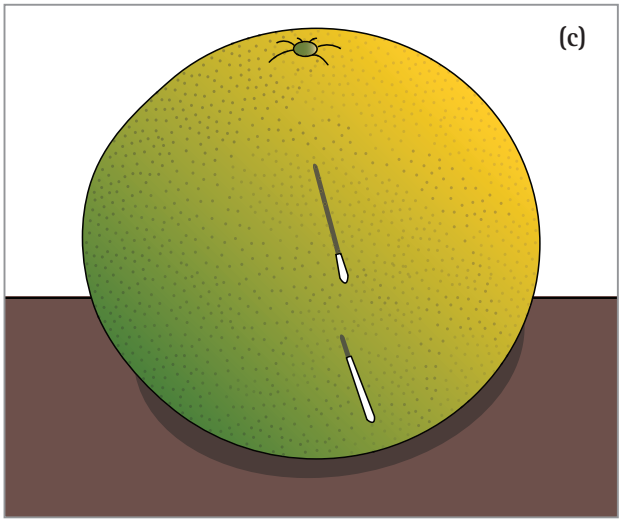

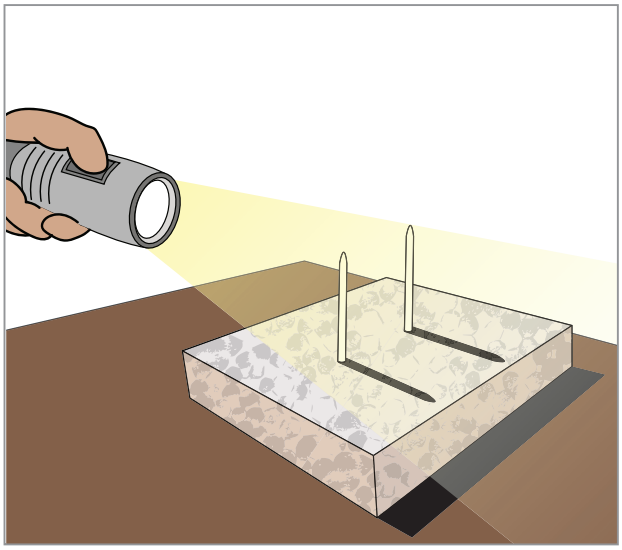

Fig. 7. When two objects of equal length stand on a flat surface, the shadows they cast are also of equal length.

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Box 4. Eratosthenes' measurement:

Eratosthenes knew that none of the tall objects (like poles) in the ancient city of Syene, Egypt, cast any shadows on the ground at noon on a particular day. He inferred that this was because the sun was directly overhead Syene at this time. In contrast, the tall structures in Alexandria, another famous ancient city further north of Syene, left observable shadows (see **Fig. 8**).

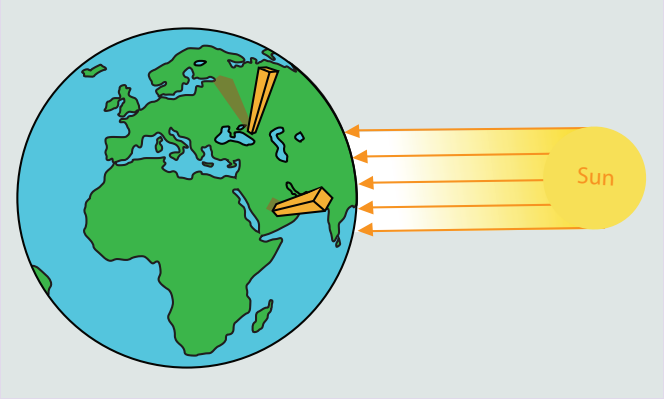

Fig. 8. Eratosthenes concluded that the earth was not flat based on the difference in the length of shadows at two places at noon on the same day.

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He concluded that the only way this could happen was if the earth were spherical. Because of its curvature, the sun would not be directly overhead at two places at different latitudes. Hence, the length of shadows cast by even identical poles at these locations would be different. Eratosthenes used these measurements to come up with an estimate for the circumference of the earth.[1]

Parting thoughts

Our senses are efficient in providing us with an understanding of the world. However, there are instances where our immediate perception of reality through these senses can be skewed and even plain wrong. This is one of the reasons why it is important for us to rely on the scientific process of making observations, conducting experiments, and arriving at conclusions after carefully considering all possibilities.

Key takeaways

- That the earth is not really flat is not a modern discovery.
- The earth appears flat because the degree of curvature of its surface is so small that it often becomes apparent to us only from great heights.
- We can infer the curvature of the earth through many simple observations, like how objects vanish from the horizon or what we can see of them from different heights.
- Another way we can infer that the earth is curved is through a simple indoor experiment to compare the length of shadows cast by two objects of equal length when affixed to a flat surface versus a curved surface.

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For further reading:

1. Brown, Cynthia Stokes. 'Eratosthenes of Cyrene'. Big History Project. Khan Academy. URL: https://www.khanacademy.org/humanities/big-history-project/solar-system-and-earth/knowing-solar-system-earth/a/eratosthenes-of-cyrene.
2. Kate, Amol Anandrao. 'Measuring Earth's Size'. i wonder... pg. 22-26. ISSN 2582-1636. URL: https://publications.azimpremjiuniversity.edu.in/3390/.

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