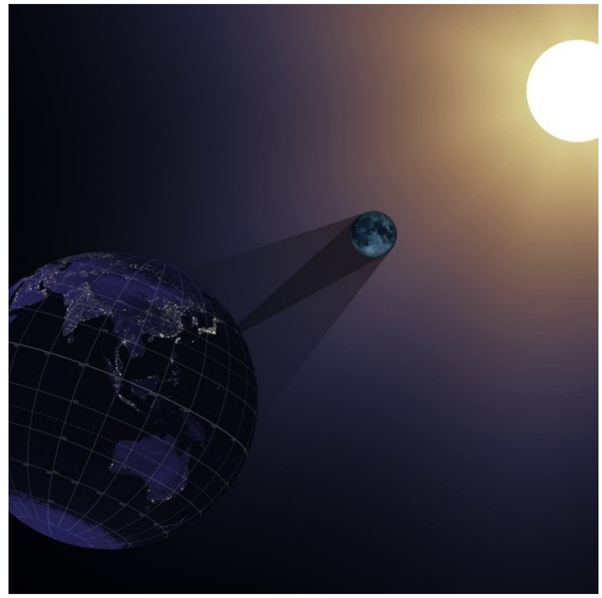
Eclipses: Earth-Moon-Sun Model



NASA Scientific Visualization Studio

Demonstration

This demonstration uses a model of the earth-moon-sun system to explain why eclipses occur. This demo is useful for illustrating why total solar eclipses are rare.

Number of Participants: Unlimited

Audience: Elementary (ages 5-10) and up

Duration: 10-20 minutes

Difficulty: Level 2

Materials Required:

- Hula-hoop (~40” diameter)
- Wooden dowel (0.25” diameter, min. 40” in length)
- Lamp (no shade) or flashlight (indoors only)
- Styrofoam ball (8” – 12”)
- Styrofoam ball (1” – 3”)
- Heavy duty tape or glue

Setup:

1. If the length of the dowel is greater than the diameter of the hula-hoop, cut the dowel to match the inner diameter of the hoop.
2. Pierce the large Styrofoam ball through the center with the dowel. Glue in place.
3. Using tape or glue, secure each end of the dowel to the hula-hoop, as shown in Figure 1.
4. Slice the small Styrofoam ball in half, core the ball, and recombine over hula-hoop ring. Glue or tape in place.

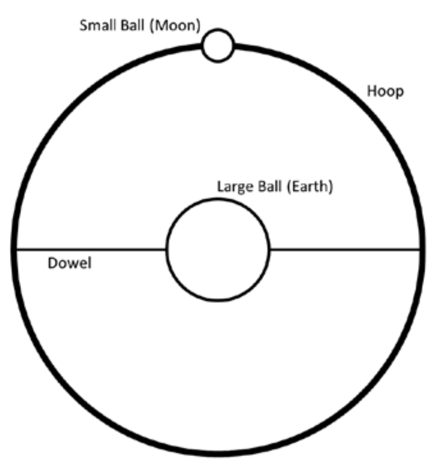


Figure 1

5. If inside, setup the light source in a dim or dark room. If outside, best if used on a sunny day.

Presenter Brief:

Eclipses are a coincidence of the geometry of the earth-moon-sun system. The moon and earth orbit their respective bodies in ellipses, not circles. The orbital plane of the moon is tilted about 5° from the Earth's orbital plane, which is represented in Figure 2a.

Physics & Explanation:

Elementary (ages 5-10):

Just like a shadow cast on the sidewalk on a bright day, the sun causes objects in space to cast shadows. There are shadows in space.

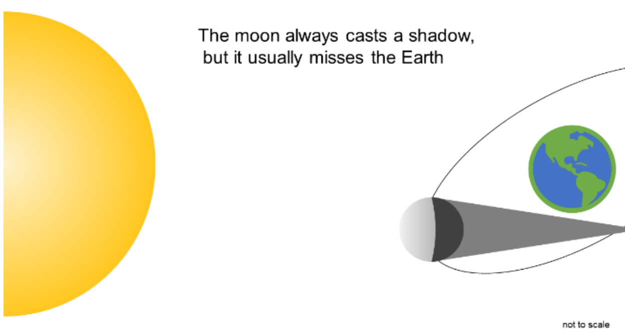


Figure 2a

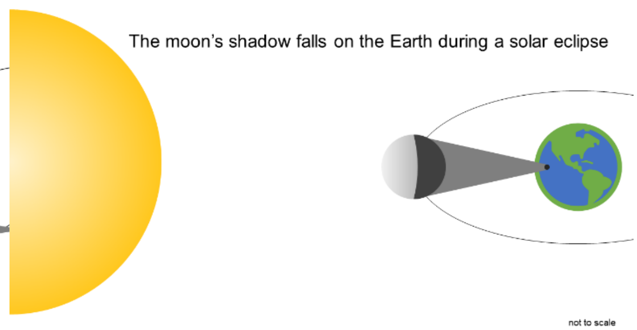


Figure 2b

Sometimes the shadow cast by the moon falls on Earth.

Holding the plane of the hoop so that it passes through the lightbulb, project the shadow of the moon so that it doesn't fall on Earth, such as in Figure 2a.

Next, tilt the hoop to move the shadow so that it falls on the surface of the Earth, like in Figure 2b.

The shadow cast by the moon can fall on Earth. This is called an eclipse.

If you're standing in any part of the shadow on Earth, you will see the moon either partially or fully covering up the sun.

Hold the hoop assembly so that the participant is between the light-source and the moon. Use the moon to block out the light-source (*do not look directly at the sun. Skip this step if using the sun as the light-source*).

During a solar eclipse, the moon covers the sun.

Just as the moon can cast a shadow on Earth, the Earth can also cast a shadow on the moon.

Hold the hoop assembly so that a shadow is cast by the Earth on the moon.

During a lunar eclipse, the moon moves into the shadow of the earth and becomes dark.

Middle (ages 11-13) and general public

Except during a lunar eclipse, half of the moon is illuminated with sunlight. As the moon orbits the Earth, we see both the lit and unlit parts. This is the moon changing phases. When the moon is in between the Earth and the sun, the moon is fully illuminated on the opposite (far) side while the side facing the earth is complete dark. This is called the *new moon*.

Ask students: Why don't we have an eclipse every time we have a new moon?

Holding the plane of the hoop so that it passes through the lightbulb, project the shadow of the moon so that it doesn't fall on Earth, such as in Figure 2a. Tilt the hoop like in Figure 2b to project the shadow on the Earth.

The orbital plane of the moon around the Earth is 5° off from the orbital plane of the Earth around the sun, as seen in Figure 4.

When the Earth is between the moon and the sun, the moon is fully illuminated from our perspective (full moon). Just as the moon's shadow is cast on Earth during a solar eclipse, the Earth's shadow is cast on the moon during a lunar eclipse.

Rotate the hoop around so the Earth is between the moon and the light source. Show the shadow of the Earth being cast on the moon.

Optional: Replace the wooden dowel with an elastic material, such as a bungie cord.

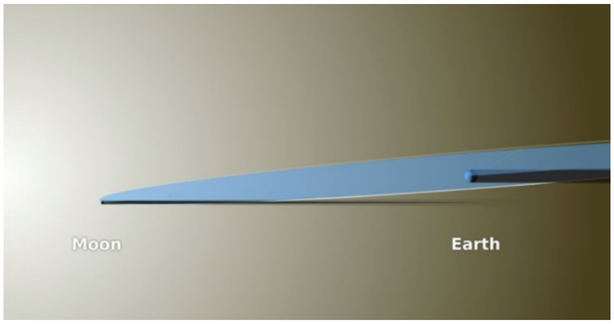


Figure 3

The distance between the Earth and the moon varies. When the moon is at the farthest point from Earth, apogee, its apparent size is too small to completely cover the disk of the sun. However, when the moon is at the closest point to Earth, perigee, its apparent size is closer to the apparent size of the sun.

Holding as shown in Figure 4, compress the hoop to deform the ring from a circle to an oval. This will change the distance between the Earth and the moon.

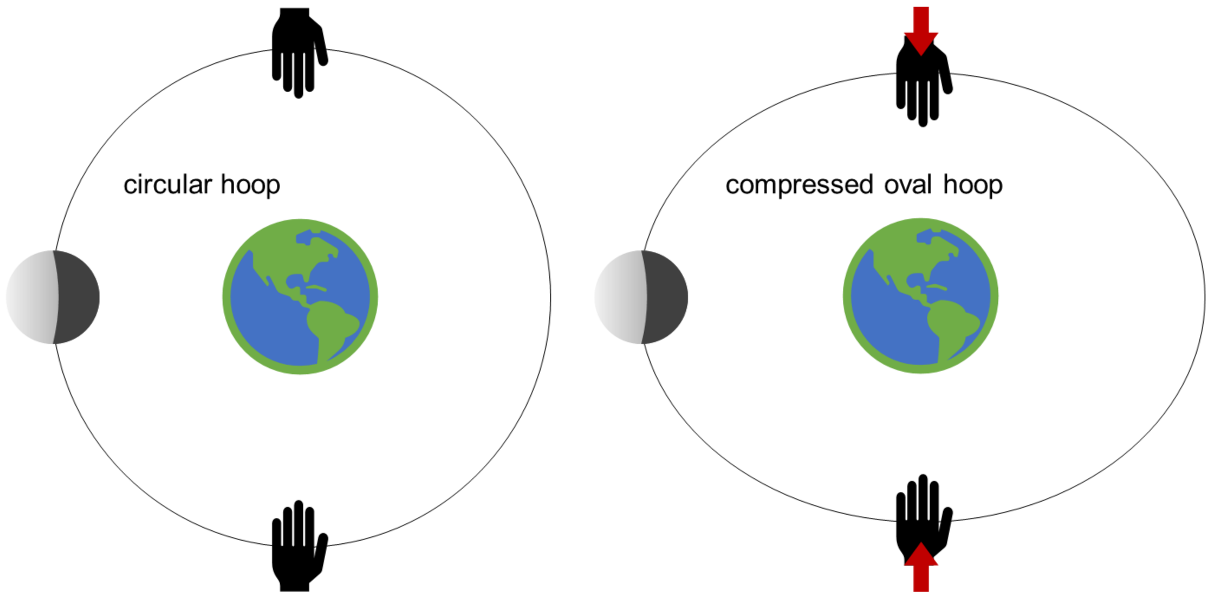


Figure 4

The distance between the Earth and the moon varies. If the moon is too far away, it will not completely cover up the moon from our perspective.

Highschool (14 +):

If working indoors, consider adding the following exercise.

> Point out that the large ball (the sun) is much larger than the small ball (the moon).

Since the distance between the moon and the Earth varies, the angular diameter of the moon in the sky also varies. For a total solar eclipse to occur, the angular size of the moon must be greater than or equal to the angular size of the sun.

Calculate the angular diameter of the moon and the sun.

$$angular\ diameter = \frac{linear\ diameter}{distance}$$

Linear diameter of the moon: $3476\ km$. Average Earth to moon distance: $384{,}000\ km$.

Linear diameter of the sun: 1.39×10^6. Average Earth to sun distance: $1.50\ \times 10^8\ km$.

$$angular\ diameter_{moon} = \frac{3476\ km}{384{,}000\ km} \times \frac{206{,}265''}{1\ radian} \times \frac{1'}{60''} \times \frac{1^\circ}{60'} \approx 0.5^\circ$$

$$angular\ diameter_{sun} = \frac{1.39 \times 10^6\ km}{1.50 \times 10^8\ km} \times \frac{206{,}265''}{1\ radian} \times \frac{1'}{60''} \times \frac{1^\circ}{60'} \approx 0.5^\circ$$

This fact is the reason we have total solar eclipses.

Additional Resources:

- Crash Course Astronomy: #5 Eclipses
  https://www.youtube.com/watch?v=PRgua7xceDA
- Seeds, Michael A. *Foundations of Astronomy*, 2003. 41-51.