ExploreLearning

Exploration Guide: 3D Eclipse

After months of easy living on the shores of Jamaica in 1504, Christopher Columbus and his crew had finally overstayed their welcome. Faced with increasingly hostile natives who threatened to cut off food supplies, Columbus came up with an ingenious plan to trick the Jamaicans.

According to popular accounts, Columbus summoned the tribal leaders to his camp. He told them that the Almighty was displeased with their actions, and would swallow the Moon from the sky. Sure enough, a few minutes later the Full Moon started to disappear! The awed chiefs begged Columbus to restore their Moon, and a short time later the Moon reappeared.

Columbus, of course, had noticed the predicted **lunar eclipse** on his calendar. Astronomers from many civilizations, from the Mayans to the Chinese, have learned to predict eclipses. By modeling the orbit of the Moon around the Earth in three dimensions, you can observe eclipses happening and understand why they are so rare.

Observing Eclipses

In this activity, you will see how the angle of the Moon's orbit influences eclipses. Note that the Sun, Moon and Earth are not to scale. (If they were, the Earth and Moon would be microscopic.) As a result, while the shadows are portrayed realistically, the angle of Moon's orbit and the duration of eclipses are distorted.

1. To observe eclipses more easily, set the **Moon angle** slider to zero. (To quickly set a slider to a value, type the value in the field to the right of the slider, and press **Enter.**) Set the **Speed** slider near the middle of its range, and click **Play** (▶). Observe the Moon in orbit around Earth on the **SIMULATION** pane. When the Moon is directly between Earth and the Sun, click **Pause** (⏸). If necessary, click **Back** to step the Moon back in

its orbit.

a. Under **Shadows,** select **Moon.** In the **S IMULATION** pane, observe the Moon's shadow in the bird's eye view above and the side view below. Does the Moon's shadow appear to hit Earth?
b. Under **Views,** select **Earth.** Note that the Moon's shadow covers only a small part of Earth. An observer standing in this shadow would experience a **total solar eclipse.** She would see the Sun gradually covered by the Moon, darkening the sky. The area of total solar eclipse, also known as the umbra, is relatively small, usually only about 250 km wide. This area is surrounded by a much larger area, called the **penumbra**, in which observers would only see a **partial solar eclipse**. What do you think this would look like?
c. Click the **Back** button until just before the Moon's shadow hits the Earth. Set the **Speed** to its minimum level, and click **Play.** Observe the path of the Moon's shadow across Earth. This is called the **path of totality.** What continents did the path of totality cross?
d. Click the **Back** button to the start of the eclipse, and make a note of the time. Click **Play,** and then **Pause** at the end of the eclipse. How long did the simulated eclipse last? In reality, solar eclipses only last a few hours.
e. Select a moderate speed, click **Play,** and wait for the next solar eclipse to occur. Note the date shown below the clock, and then observe a few more eclipses. When the **Moon angle** is set to 0°, how often do solar eclipses happen? Do you think this is realistic?

2. Click **Reset** () and select the **Standard** view. Turn on the **Earth** shadow and click **Play. Pause** the simulation when the Moon just begins to enter Earth's shadow.

a. Select the **Moon** view and set the speed to minimum. Observe the **lunar eclipse** that occurs as Earth's shadow crosses over the Moon. Because the Earth is much larger than the Moon, the entire Moon will be covered by Earth's shadow. Lunar eclipses are much easier to observe because they can be seen by anyone on the night side of the

Earth. Like solar eclipses, lunar eclipses only last a few hours.

b. Observe several lunar eclipses, noting the date for each. Do you think lunar eclipses really occur that often?

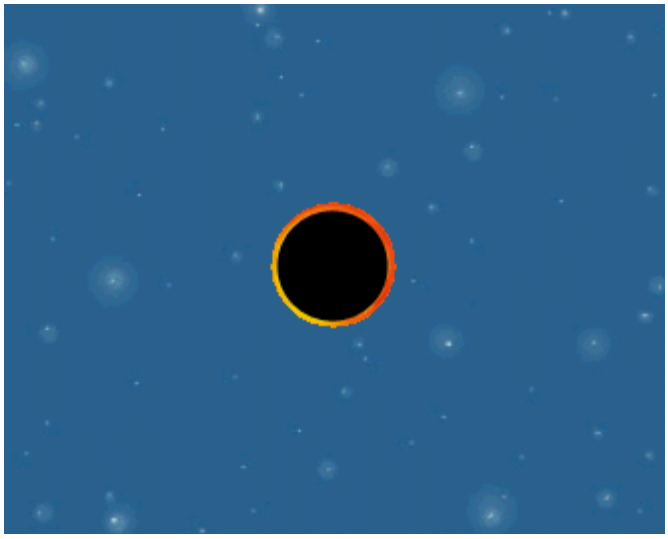
3. The reason solar and lunar eclipses don't occur every month is that the Moon's orbit is tilted at an angle of 5° relative to the plane of Earth's orbit around the Sun. To model this, set the **Moon angle** slider to 5.0°. Click **Reset** and select the **Standard** view. Under **Shadows**, select **Moon**.

   a. Select a moderate speed and click **Play.** **Pause** the Moon when it is directly between the Earth and the Sun. Observe the side view at the bottom of the **SIMULATION** pane. Does the Moon's shadow hit the Earth? Why or why not?
   b. Select the **Earth** view, click the **Back** button several times, and observe the path of the Moon's shadow at a slow speed. Will a total solar eclipse be visible from Earth? Where would you have to travel to see the eclipse?
   c. Select the **Standard** view, increase the speed, and click **Play**. **Pause** the Moon when it is between the Earth and Sun again, around February 11. Does the Moon's shadow hit the Earth on this day? Why or why not?
   d. Try finding other solar eclipses. Record the date for each eclipse you find. How many solar eclipses did you find in a year? In reality, there are usually two solar eclipses in a year, but they are not always total eclipses.
   e. Try finding all the lunar eclipses in a year. How many lunar eclipses can you find? In reality, there are usually two lunar eclipses in a year.

4. Set the **Moon distance** slider to 1.3 and the Moon angle slider to 0.0°. Click **Play,** and then click **Pause** on January 10. Observe the Moon's shadow on the **Standard** view and the **Earth** view.

   a. Does the Moon's shadow touch the Earth? Why not?
   b. Because the Moon's orbit is not perfectly circular, the Moon is occasionally too far away to cast a shadow on the Earth. Instead of a

total solar eclipse, observers on Earth would see an annular solar eclipse, as shown below. The sunlight would dim, although not as much as during a total eclipse.



c. Experiment with a variety of other angles and Moon distances. (Remember, in reality these values are fixed.) What is the relationship between the angle of the Moon's orbit and the frequency of eclipses? How is the frequency of eclipses affected by changing the Moon's distance?
d. Summarize your findings by answering these questions. Based on what you have observed, why do eclipses only happen a few times a year? Why is it so rare to observe a total solar eclipse?
