

## Teacher Guide: 3D Eclipse



### Learning Objectives

Students will ...

- Learn what causes solar and lunar eclipses to occur.
- Observe the path of totality during a solar eclipse.
- Observe the Moon moving into Earth's shadow during a lunar eclipse.
- Explain why eclipses do not occur every month.
- Explain why it is more likely to see a lunar eclipse than a solar eclipse.



### Vocabulary

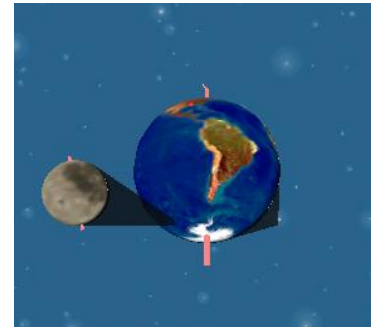
eclipse, lunar eclipse, path of totality, penumbra, solar eclipse, umbra



### Lesson Overview

When the movements of the Earth and Moon are viewed in two dimensions, it looks like the Moon should pass through Earth's shadow every time it orbits Earth. This would cause a lunar eclipse every month. Similarly, a two-dimensional image would show the Moon's shadow crossing Earth's surface every month, leading to a monthly solar eclipse as well.

To understand why eclipses do *not* occur every month, it is necessary to consider the tilt of the Moon's orbit in three dimensions. This factor is illustrated in the *3D Eclipse Gizmo*™.



**The Moon's shadow strikes Earth.**

The Student Exploration sheet contains two activities:

- Activity A – Students determine how the tilt of the Moon's orbit affects the occurrence of solar eclipses.
- Activity B – Students determine how the tilt of the Moon's orbit affects the occurrence of lunar eclipses.



### Suggested Lesson Sequence

1. **Pre-Gizmo activity** (🕒 30 – 45 minutes)  
Cover eclipse basics in two dimensions with the *Eclipse Gizmo* or the *2D Eclipse Gizmo*. After finishing one of those Gizmos, ask your students how often they would expect an eclipse based on what they have seen. Do eclipses really occur every month? At this point, you are ready to begin the *3D Eclipse Gizmo*.
2. **Prior to using the Gizmo** (🕒 10 – 15 minutes)  
*Before* students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. (These questions ask students about shadows while they stand in front of a lamp. If you are able, allow students to stand up and do the activity in the classroom.) Discuss student answers as a class. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations, such as how to take Gizmo snapshots.

3. **Gizmo activities** (🕒 15 – 20 minutes per activity)  
 Assign students to computers. Students can work individually or in small groups. Have students work through the activities in the Student Exploration, using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (🕒 15 – 20 minutes)  
 As students are working or just after they are done, discuss the following questions:

- Why don't eclipses happen every month?
- How long do solar and lunar eclipses last in the Gizmo? [Because of the scale issues, eclipses last much longer in the Gizmo than in real life. Real eclipses last for a few hours rather than a few days as shown in the Gizmo.]
- Why do solar eclipses tend to happen at similar times of the year to lunar eclipses?
- Why do you think it is more likely that you will be able to witness a lunar eclipse than a solar eclipse?

5. **Follow-up activities** (🕒 variable)

Have your students look up the dates of upcoming eclipses (see table at right; total eclipses are marked in red). Ask them if there is a pattern. Do eclipses tend to happen at a certain time of year? Do solar eclipses occur near lunar eclipses?

Students should notice that solar and lunar eclipses tend to occur about 15 days apart, within the same cycle of Moon phases. Students also should notice that consecutive solar and lunar eclipses occur about every  $5\frac{3}{4}$  months. See the **Scientific Background** below for an explanation.

Solar eclipses	Lunar eclipses
Jul. 11, 2010	Jun. 26, 2010
Jan. 4, 2011	Dec. 21, 2010
Jun. 1, 2011	Jun. 15, 2011
Nov. 25, 2011	Dec. 10, 2011
May 20, 2012	Jun. 4, 2012
Nov. 13, 2012	Nov. 28, 2012
May 10, 2013	Apr. 25, 2013
Nov. 3, 2013	May 25, 2013
Apr. 29, 2014	Oct 18, 2013
Oct. 23, 2014	Apr. 15, 2014

If an eclipse will be visible in your area, make plans to go see it. For a lunar eclipse, no special equipment is necessary although a pair of binoculars will be useful. **WARNING:** A solar eclipse should not be viewed directly unless you have specialized equipment. Permanent eye damage could result from looking at the Sun directly, especially through a telescope or binoculars. Instead, punch a small hole in a piece of cardboard and project an image of the Sun onto a sheet of paper held behind the cardboard.



### Scientific Background

A total solar eclipse occurs when the Moon's shadow crosses over Earth's surface. The tip of the Moon's umbra traces out a narrow *path of totality* across the surface. Only observers in the path of totality experience a total solar eclipse. A total lunar eclipse occurs when the Moon is completely darkened by Earth's umbra. In contrast to a total solar eclipse, which can only be viewed by observers in the path of totality, a total lunar eclipse is visible to any observer on the night side of Earth. Therefore, it is much more common to experience a lunar eclipse than a solar eclipse.

For a solar or a lunar eclipse to occur, the Earth, Moon, and Sun must be aligned. Because the Moon's orbit is tilted  $5.14^\circ$  relative to the plane of Earth's orbit, this alignment does not occur every time the Moon orbits Earth. In most months, the Moon passes above or below Earth's shadow as it passes behind Earth. Similarly, the Moon's shadow usually passes above or below Earth when the Moon moves between Earth and the Sun.

Solar and lunar eclipses can occur when the Moon is near the plane of Earth's orbit while in the New Moon or Full Moon phases. This alignment occurs about twice a year, or every  $5\frac{3}{4}$  months on average. In most cases, a solar eclipse will either precede or follow a lunar eclipse by about 15 days. It is rare for both of these eclipses to be total.

In the images below, the left image shows an alignment in which the Moon is above Earth's umbra as it passes behind Earth. In this situation, no eclipse will occur. The image at right shows the Moon aligned with the Sun and Earth as it passes behind Earth. In this case, a lunar eclipse will occur. (Note: Sizes are not to scale.)



### Historical Connection: The eclipse that proved Einstein right

In 1915, after years of work, Albert Einstein presented his general theory of relativity, a theory that provided a direct challenge to Newton's law of gravity. One of the main differences between the two theories was the treatment of light. In Newton's theory of gravity, the force of gravity is proportional to the product of the masses of the objects involved. Light, which has no measurable mass, should be unaffected by gravity. Einstein's theory stated that massive objects would warp space, causing light to curve as it passed by massive bodies.

Shortly after general relativity was proposed, Arthur Eddington came up with a way to test this distortion of light. He realized that light from distant stars would be curved as it passed by the Sun. Normally these stars are not visible because of the brightness of the Sun, but they become visible during a solar eclipse. The test was conducted during the total solar eclipse of May 29, 1919, in which it was found that, just as Einstein predicted, light from distant stars was curved by the Sun. This proof of general relativity made Einstein a worldwide celebrity.



### Selected Web Resources

Eclipse dates and maps (NASA): <http://eclipse.gsfc.nasa.gov/eclipse.html>  
Tilt of Moon's orbit: <http://www.csulb.edu/~htahsiri/animate/Moon%20tilt%20orbit.html>,  
[http://starryskies.com/The\\_sky/events/lunar-2003/eclipse2.html](http://starryskies.com/The_sky/events/lunar-2003/eclipse2.html)  
Eclipse proves relativity: <http://www.firstscience.com/site/articles/coles.asp>,  
[http://www.simonsingh.net/1919\\_Eclipse.html](http://www.simonsingh.net/1919_Eclipse.html)

Related Gizmos:

*Phases of the Moon:* <http://www.explorellearning.com/gizmo/id?613>  
*Eclipse:* <http://www.explorellearning.com/gizmo/id?644>  
*2D Eclipse:* <http://www.explorellearning.com/gizmo/id?556>  
*Penumbra Effect:* <http://www.explorellearning.com/gizmo/id?469>