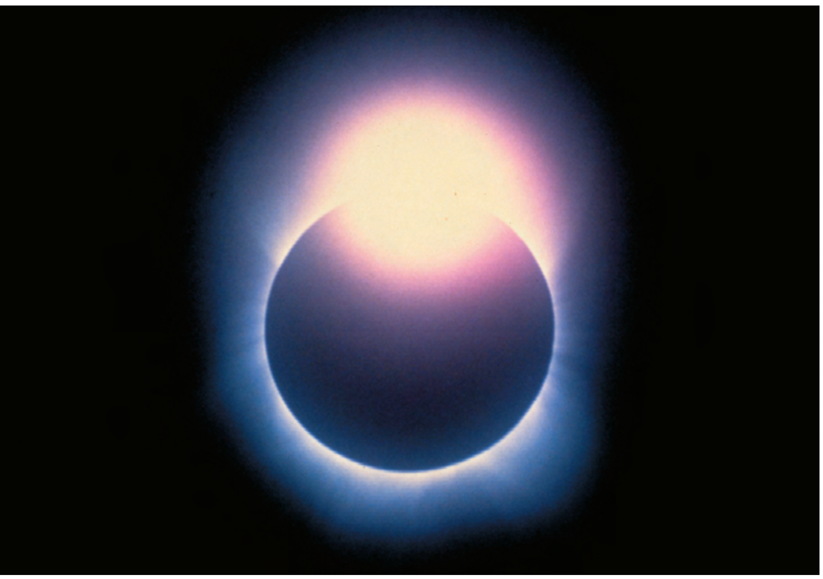
LESSON 6

Solar and Lunar Eclipses



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The "diamond ring" effect occurs when only the barest sliver of the Sun is visible around the Moon during a total solar eclipse.

INTRODUCTION

In Lesson 5, you investigated how relative positions of the Sun, Earth, and Moon affect our view of the Moon and its changing phases. Sunlight reflects off the lunar surface, and when the Moon is full, nighttime on Earth can look almost like day. But what happens when Earth's shadow falls on the full moon? A lunar eclipse occurs. At other times, the new moon may move in front of the Sun and block its light. It's a solar eclipse! In this lesson, you will determine why eclipses can occur during each of these phases. You also will analyze the Moon's orbital plane and Earth's revolution to determine why solar and lunar eclipses do not occur each month.

OBJECTIVES FOR THIS LESSON

Model shadows cast by the Moon and Earth.

Analyze the conditions under which the Moon and Earth's shadows cause eclipses.

Describe the phases during which lunar and solar eclipses occur.

Analyze solar and lunar eclipse data and compare it to phase data.

Develop working definitions for the terms "umbra" and "penumbra."

Getting Started

1. Watch the video *Sun, Earth, Moon.* Discuss it with your class.

2. What do you already know about eclipses? What do you want to know about eclipses? Discuss these questions with the class. Your teacher may record your ideas.

3. Your teacher will set up a lamp in the center of the room. Stand with a partner so that you can see your shadow. Work with your class to examine how you and your 7.5-cm sphere can cast shadows and can block, or *eclipse,* light.

4. Relate what happened with the sphere to what happens to the Moon and Earth during an eclipse. Record in your notebook what you think the terms "lunar eclipse" and "solar eclipse" mean.

MATERIALS FOR LESSON 6

For you

1 copy of Student Sheet 6.2a: Geometry of Eclipses

For you and your partner

1 white sphere, 7.5 cm
1 pencil (to support the sphere)

For your group

1 Sun-Earth-Moon Board™
1 set of 8 rods, labeled #1–#8
1 rod labeled "E"
1 globe of Earth, 12 cm
1 Mini Maglite®
2 AA batteries
1 white sphere, 3.5 cm
5 removable dots
1 toothpick, 1 cm of the tip
Modeling clay, bead-sized amount
1 foam sleeve (optional)

Inquiry 6.1
Investigating Lunar and Solar Eclipses

PROCEDURE

1. Model a full moon using the large white 7.5-cm sphere (the Moon), a Mini Maglite (the Sun), and yourself (Earth).

2. Model the conditions under which a full moon is totally eclipsed (or its light is blocked), as shown in Figure 6.1. Share roles with your group so that everyone has a chance to model Earth. What is casting the shadow on the Moon? Draw this type of eclipse in your notebook. Label the Moon, Sun, and Earth in your drawing. Draw the shadow. Write a sentence that describes your drawing.

3. Now model the conditions under which a full moon is partially eclipsed (its light is only partially blocked). Where does the shadow fall on the Moon? Draw this type of eclipse in your notebook. Label your drawing. Write a sentence that describes your drawing.

4. Model a new moon using your sphere (Moon), Mini Maglite (Sun), and yourself (Earth).

5. Model the conditions under which a new moon can totally eclipse the Sun's light. Have your partner examine the shadow cast by the new moon. Where does the shadow fall? Draw this type of eclipse in your notebook. Label and describe your drawing.

6. Again model a new moon eclipsing the Sun's light, but this time increase the distance between your head (Earth) and the sphere (new moon). What happens to the eclipsed light? Have your partner examine the shadow cast by the new moon. Where does it fall? Draw your results in your notebook and label them.

7. Model a new moon eclipsing the Sun's light again, but this time, lower the sphere (new moon) so that it is only partially in line with your head (Earth) and the Mini Maglite (Sun). What happens to the eclipsed light? Have your partner examine the shadow cast by the new moon. Where does it fall? Draw your results and label them.

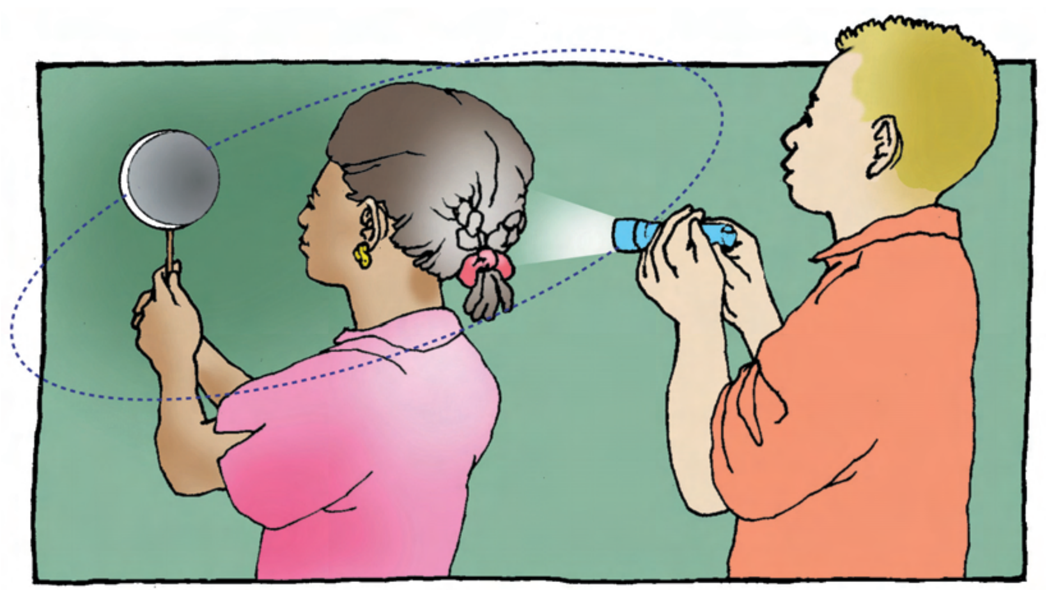


Figure 6.1 *Can you eclipse your full moon?*

REFLECTING ON WHAT YOU'VE DONE

1. Read "Eclipses."

2. Return to each of your drawings from Inquiry 6.1. Give each drawing one of the following titles: "Total Lunar Eclipse," "Total Solar Eclipse," "Partial Lunar Eclipse," "Partial Solar Eclipse," or "Annular Solar Eclipse."

3. Use the information in Table 6.1: Solar and Lunar Eclipses 2001, Table 6.2: Full and New Moon Dates 2001, and your observations from Inquiry 6.1 to answer the following questions in your notebook:

   A. During what phase does a lunar eclipse occur? Give one date as an example.

   B. During what phase does a solar eclipse occur? Give one date as an example.

   C. How many lunar eclipses occurred during the year 2001?

   D. How many solar eclipses occurred during the year 2001?

   E. Did an eclipse occur with each full and new moon? Explain.

   F. Under what conditions does a total solar eclipse occur?

   G. Under what conditions can a partial solar eclipse occur?

   H. Under what conditions does an annular solar eclipse occur?

Table 6.1 Solar and Lunar Eclipses 2001

Month	Type of Eclipse	Description
Jan 9	Lunar	Total
June 21	Solar	Total
July 5	Lunar	Partial
Dec 14	Solar	Annular
Dec 30	Lunar	Penumbral

Table 6.2 Full and New Moon Dates 2001

Date	Lunar Phase	Date	Lunar Phase
Jan 9	Full	July 20	New
Jan 24	New	Aug 3	Full
Feb 8	Full	Aug 18	New
Feb 23	New	Sept 2	Full
Mar 9	Full	Sept 17	New
Mar 24	New	Oct 2	Full
April 7	Full	Oct 16	New
April 23	New	Oct 31*	Full
May 7	Full	Nov 15	New
May 22	New	Nov 30	Full
June 5	Full	Dec 14	New
June 21	New	Dec 30	Full
July 5	Full		

* When two full moons occur in one calendar month, we call the second full moon a "blue moon." The expression "once in a blue moon" refers to rare occurrences such as this.

Inquiry 6.2
Analyzing the Geometry of Eclipses

PROCEDURE

1. Set up your SEM Board as you did in Lesson 5. Put your small sphere on rod #1 and your globe of Earth on the rod labeled "E."

2. Place a removable dot in the center of your workspace, and add four additional removable dots approximately 30 cm from that dot, forming a cross, as you did in Lesson 4. Label the center dot "S." Working counterclockwise, label the outside dots A, B, C, and D, as you did in Lesson 4 (see Figure 4.3). Each dot will represent a position of the Earth-Moon system as it orbits the Sun.

3. Position the SEM Board so that the rod of your globe is approximately over the dot labeled "A." Position the board so that rod #1 is closest to your "S" dot, as shown in Figure 6.2.

4. Hold the Mini Maglite parallel to the table and over the "S" so that it shines on the small sphere. Move the small sphere (your Moon) from rod #1 through to rod #8. Shine the Mini Maglite on the sphere each time. Which rod holds the new moon (N)? Which rod holds the full moon (F)? Mark an "N" inside the Moon in Box A of Student Sheet 6.2 that shows a new moon. Mark an "F" inside the Moon in Box A of Student Sheet 6.2 that shows a full moon.

5. Put the sphere on the rod that holds the new moon. With the Mini Maglite parallel to the tabletop and shining on the small sphere, examine Earth. Does the new moon cast a shadow on Earth? Discuss your observations with your group.

6. Put the sphere on the rod that holds the full moon. With the Mini Maglite parallel to the tabletop and shining on the small sphere, examine Earth. Does Earth cast a shadow on the full moon? Discuss your observations with your group.

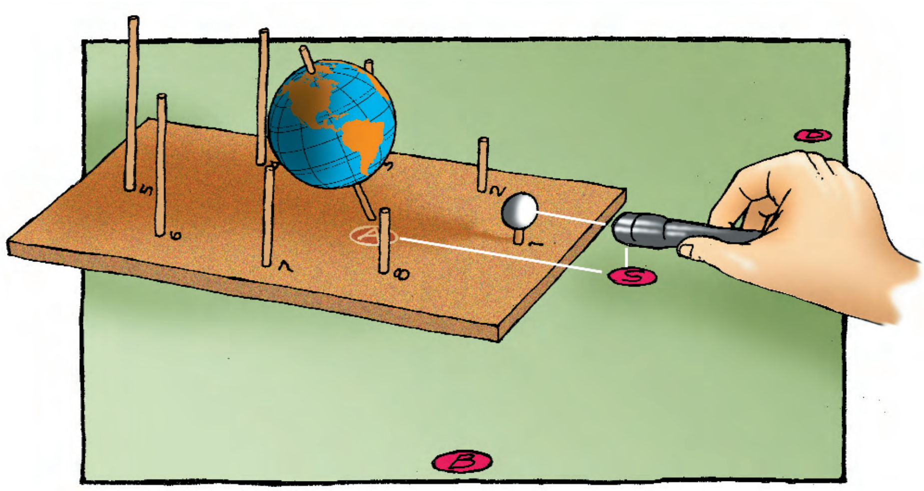


Figure 6.2 *Set up your model as shown. Shine the Mini Maglite® on the small sphere, keeping the head of the Mini Maglite® over the "S" and facing rod #1. Hold the Mini Maglite® parallel to the table.*

7. Now slide your SEM Board counterclockwise around your Mini Maglite until the axis of your globe rests approximately over the dot labeled "B," as shown in Figure 6.3. This models Earth's orbit around the Sun. How many months later does dot "B" represent? Record this time on Student Sheet 6.2.

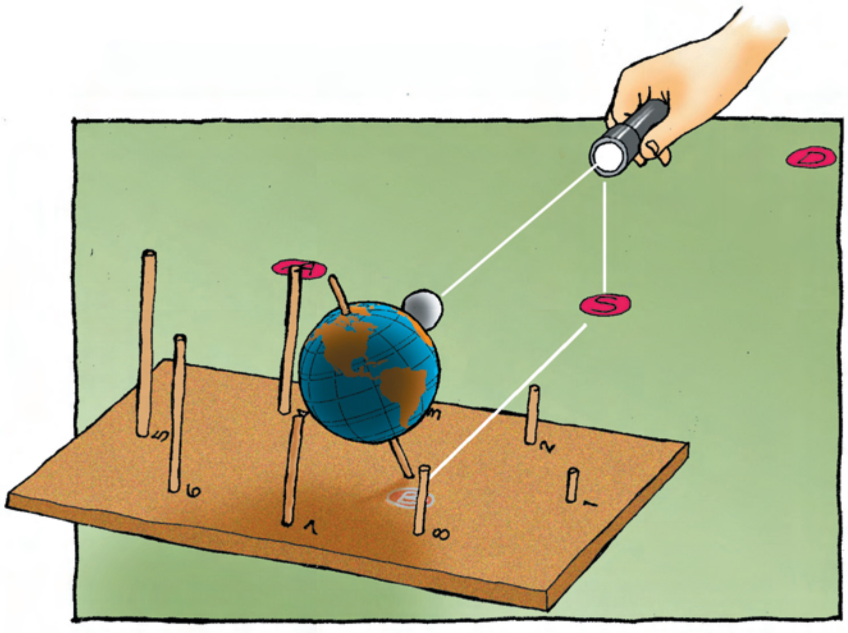


Figure 6.3 *Move your SEM board counterclockwise around your Mini Maglite® to dot "B." Hold the Mini Maglite® parallel to the table, over the dot marked "S." Shine the light on the sphere.*

8. Put the small sphere on rod #3. Keep the Mini Maglite over the dot labeled "S," but turn the light so that it shines on the sphere in its new position.

9. Move the small sphere (the Moon) from rod to rod. Shine the Mini Maglite on the sphere each time. Which rod now holds the new moon? Mark an "N" inside the new moon in Box B on Student Sheet 6.2. Can you create a solar eclipse (cast a shadow on Earth) with your new moon? Which rod now holds the full moon? Mark an "F" inside the full moon in Box B on Student Sheet 6.2. Can you create a lunar eclipse (cast a shadow on your full moon)? Discuss your observations.

10. Repeat Steps 7–9 with the dots labeled "C" and "D." Keep the Mini Maglite over the dot labeled "S" but face it toward the sphere each time. Discuss your observations each time. Record the "N" and "F" in Boxes C and D on Student Sheet 6.2 each time.

11. Keep your SEM Board over dot "D." Place the tip of the toothpick on your globe to show where your city or town is located. Shine the Mini Maglite on your globe. Move the small white sphere from rod to rod. Examine the umbra and penumbra of a shadow cone in Figure 6.4. Can you see the umbra and penumbra of the Moon's shadow on the globe? Is your city experiencing a total solar eclipse, partial solar eclipse, or no eclipse? What countries are experiencing a total solar eclipse? Rotate your globe to examine the "path of totality." Is your city in this path? Discuss your findings with your group.

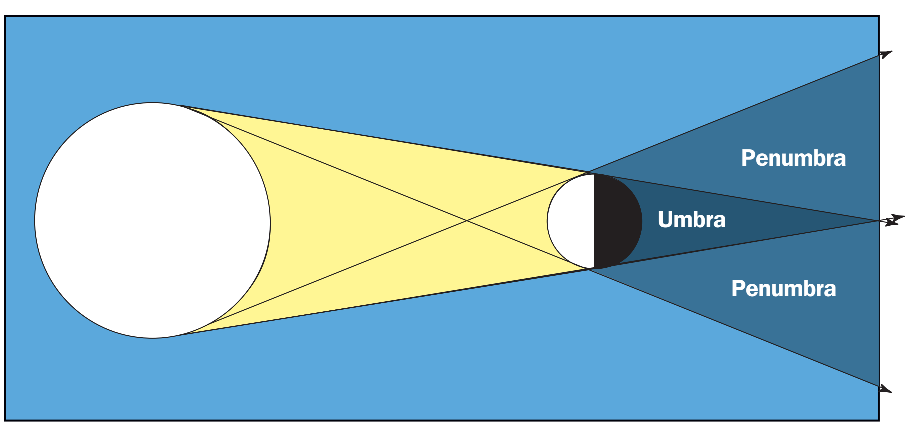


Figure 6.4 *Umbra and penumbra of a shadow cone*

REFLECTING ON WHAT YOU'VE DONE

1. Discuss your results of Inquiry 6.2 with your class. Then, in your notebook write one paragraph summarizing your observations of the Inquiry.

2. Examine the data in Table 6.3 Solar and Lunar Eclipses 2002, Table 6.4 Solar and Lunar Eclipses 2003, and Table 6.5 Solar and Lunar Eclipses 2004. Use these data and your observations from Inquiry 6.2 to answer the following questions in your notebook:

   A. About how often do lunar and solar eclipses occur each year?

   B. Why don't solar and lunar eclipses occur every month?

   C. Count the number of days between each solar and lunar eclipse. Is there a pattern? What do you notice? Why do you think this is?

   D. What would have to happen for lunar and solar eclipses to occur every month?

3. Create your own working definitions of the terms "umbra" and "penumbra." Record them in your notebook.

4. With your class, return to the Question D folder (from Lesson 1). Is there anything you would now change or add? Discuss your ideas with the class.

Table 6.3 Solar and Lunar Eclipses 2002

Date	Type of Eclipse	Description
May 26	Lunar	Penumbral
June 10	Solar	Annular
Nov 20	Lunar	Penumbral
Dec 4	Solar	Total

Table 6.4 Solar and Lunar Eclipses 2003

Date	Type of Eclipse	Description
May 16	Lunar	Total
May 31	Solar	Annular
Nov 8–9	Lunar	Total
Nov 23	Solar	Total

Table 6.5 Solar and Lunar Eclipses 2004

Date	Type of Eclipse	Description
Apr 19	Solar	Partial
May 4	Lunar	Total
Oct 14	Solar	Partial
Oct 28	Lunar	Total

ECLIPSES

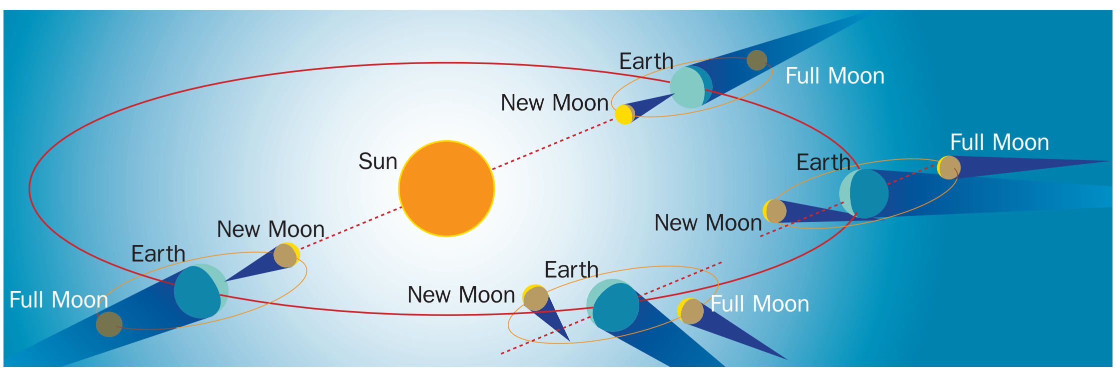
True or False?
Which of the following statements is true?

- An eclipse of the Sun occurs when an invisible dragon eats the Sun.
- During eclipses, poisons drop from the sky.
- An eclipse is a sign that the world is coming to an end.

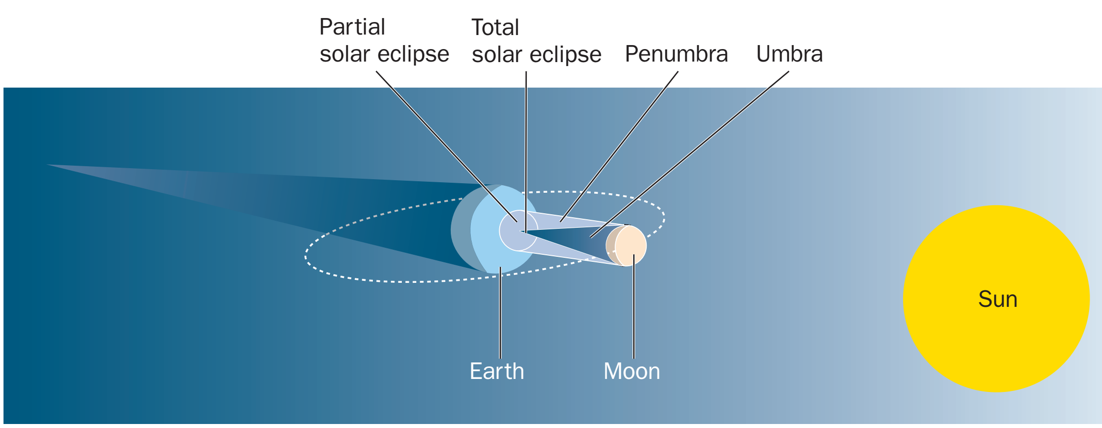
The answer? None of these statements is true. But people from cultures all over the world created these and other stories to explain the mysterious disappearance of the Sun and Moon from the sky.

Today, we know how and why eclipses take place. While eclipses have nothing to do with dragons, poisons, or the end of time, they are amazing celestial spectacles.

Solar Eclipse
A solar eclipse occurs when the Moon comes directly between Earth and the Sun. The key word is *directly,* because the Moon orbits Earth every month, and every month the Moon casts



Eclipses can happen only when the Sun and Earth are in line with the full moon or new moon. At all other times, the shadows of the Moon and Earth fall into space.



Geometry of Sun-Earth-Moon system during a solar eclipse a shadow. We don't have a solar eclipse every month because the Moon's shadow falls either above or below Earth during most months. But on rare occasions, when the Sun, Earth, and Moon are aligned just right, the Moon's shadow falls directly on Earth.

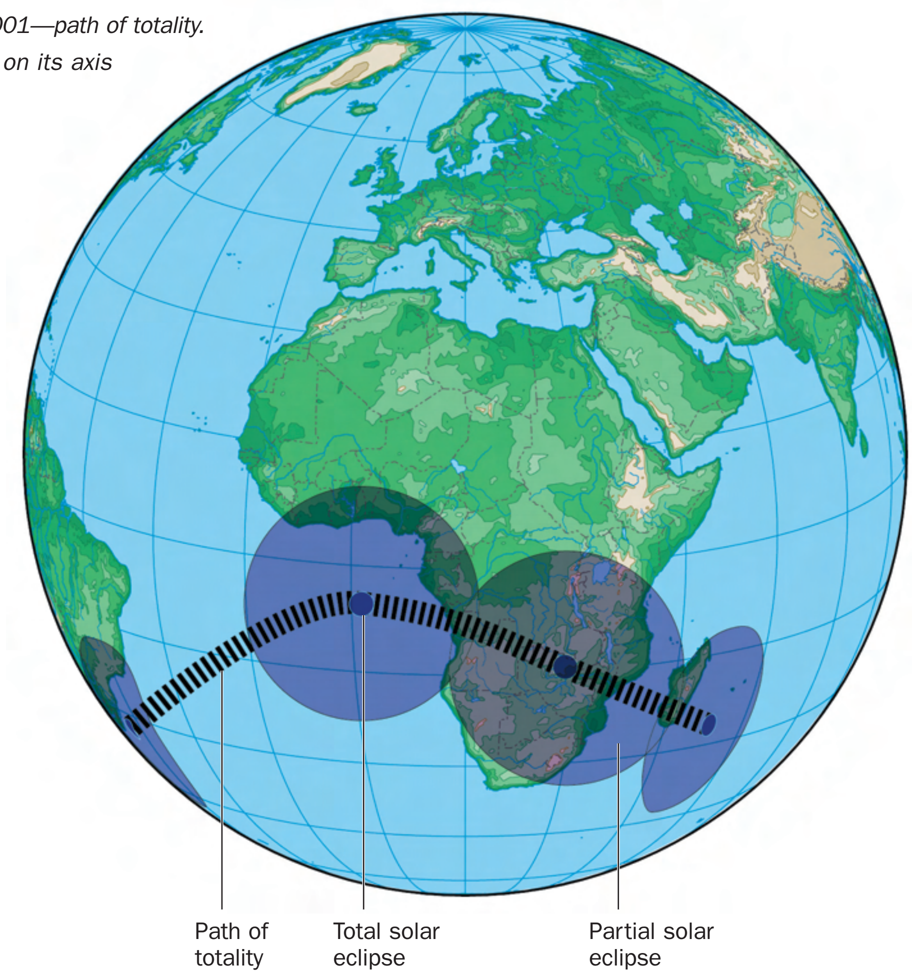
During a solar eclipse, the darkest part of the Moon's shadow cone, called the "umbra," is often only about 250 kilometers in diameter. As the Earth spins, different parts of it fall within the umbra. People who happen to be in the umbra can see a total blocking of the Sun, or a total solar eclipse. During a total solar eclipse, the air cools and daylight disappears. It becomes dark enough to see stars! For a few breathless minutes, we can see what it's like to live in a sunless world.

Outside the narrow path of the umbra, the Moon blocks only part of the Sun and creates a partial solar eclipse. A shadow is cast, but it isn't as dark as the umbra. This lighter part of the shadow cone is called the "penumbra." Because the penumbra is much larger than the umbra, a greater area of Earth experiences a partial eclipse than a total eclipse.

Annular Eclipse

In an annular eclipse, most of the Sun is covered, but an annulus (which means "ring" in Latin) of light surrounds the darkened Moon. To understand an annular eclipse, remember that the Moon's orbit around Earth is an ellipse, not a circle. As a result, the Moon's

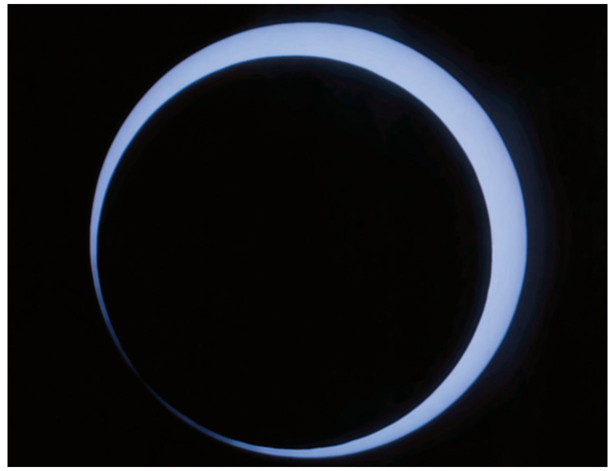
Total solar eclipse of June 21, 2001—path of totality. The path forms as Earth rotates on its axis beneath the Moon's shadow.



distance from Earth varies. When the Moon is closer to Earth, it covers the Sun completely, creating a total solar eclipse. When the Moon is farther away, it appears smaller and cannot completely cover the Sun.

Lunar Eclipse

In a lunar eclipse, Earth comes directly between the Sun and Moon—an alignment that puts the Moon in Earth's shadow. When the entire full moon falls within the center of Earth's shadow, or umbra, we have a total lunar eclipse. Everyone on the night side of the Moon (half the globe!) can see such an eclipse. Depending on how much dust and how many clouds are in Earth's atmosphere, the Moon will appear dark brown, red, orange, or yellow. This is because light bounces off Earth, passes through Earth's atmosphere, and creates a glow on the Moon.



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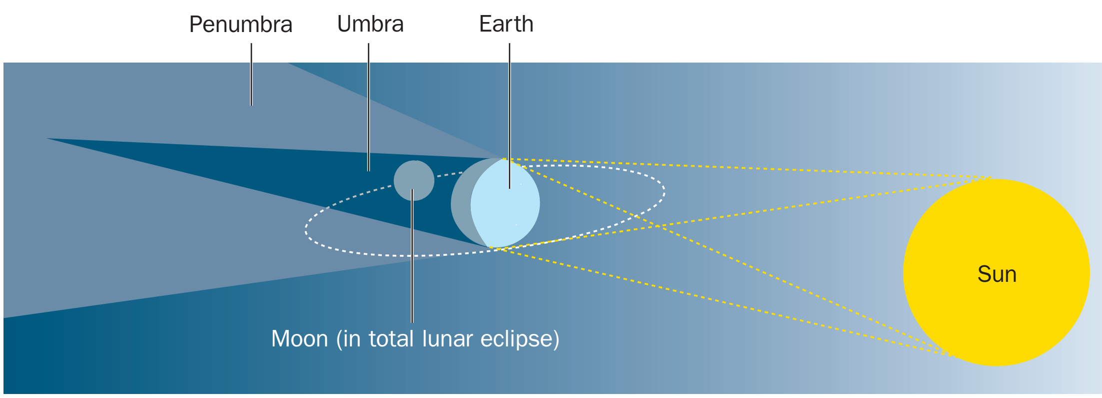
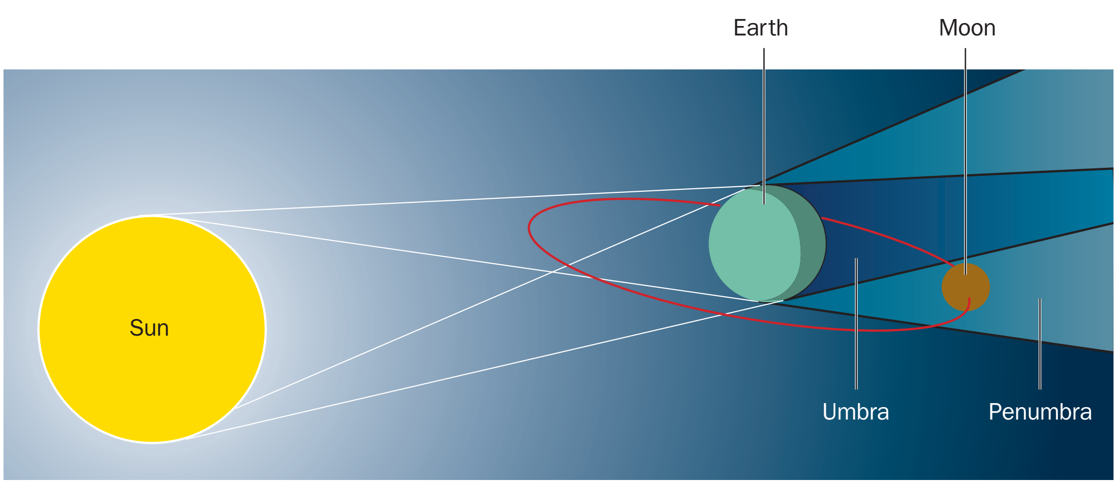
Annular eclipse of the Sun. Annulus means "ring."



A total lunar eclipse occurs when the Moon is in the umbra of Earth's shadow.



A penumbral lunar eclipse occurs when the Moon is in the penumbra of Earth's shadow.

A partial lunar eclipse occurs when only part of the Moon passes through the Earth's umbra. A penumbral lunar eclipse occurs when the Moon passes through only the lighter part of Earth's shadow cone—the penumbra. Neither of these lunar eclipses is as colorful as a total eclipse.

Look in astronomy field guides for the dates and locations of future eclipses. The next time that you have an opportunity to view a solar or lunar eclipse, don't pass it up. Whether you watch the disappearance of the Sun as the Moon passes in front of it in the middle of the day, or if you watch the transformation of a full moon into an orange-red disk, it is a worthwhile experience. □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An eclipse of the Moon. When the Moon is totally eclipsed, it appears dark brown, red, orange, or yellow.

Pinhole Projectors

Solar eclipses are beautiful events, but watching a solar eclipse can damage your eyes even if only a small part of the Sun is visible. How can you watch a solar eclipse safely? One way is with a pinhole projector.

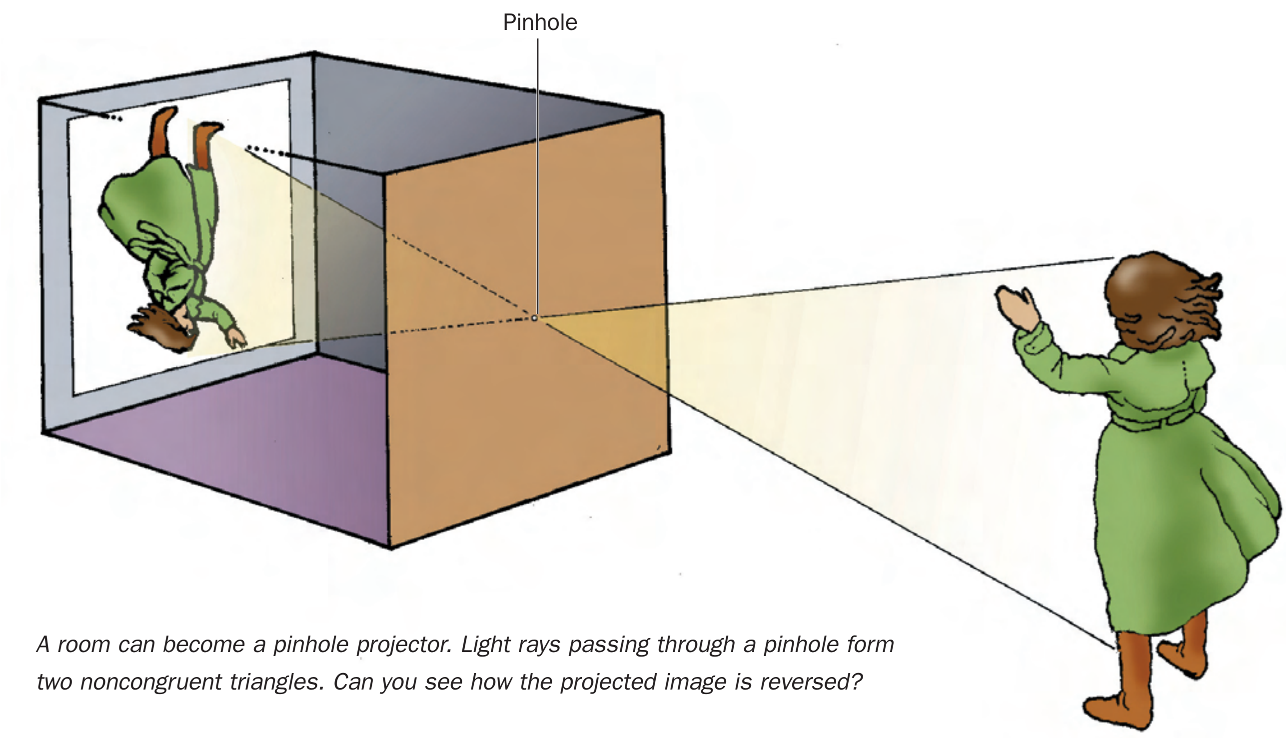
You can turn your bedroom into a pinhole projector that can be used as a solar eclipse viewing area. On a sunny day, make your room very dark. Cover your windows using newspaper, butcher paper, or cardboard. Make a small hole in the window cover, and sunlight will stream through the hole. On the wall opposite your window, you will see the view outside your window—upside down!

It sounds like magic, but it's not. It's physics.

Pinhole History

A Chinese philosopher named Mo Ti wrote about the physics of pinholes 2500 years ago! Mo Ti knew that light travels in straight lines, and that when rays pass through a hole, they cross (see the illustration). The top of an object forms the bottom of an image, and vice versa.

One hundred years after Mo Ti, Aristotle observed that the openings between the leaves of a tree worked like tiny pinholes to cast images of the Sun on the ground during a partial eclipse of the Sun. He recognized that the smaller the hole, the sharper the image. But many more centuries would go by before people understood how to use pinholes in their work.



A room can become a pinhole projector. Light rays passing through a pinhole form two noncongruent triangles. Can you see how the projected image is reversed?

Pinholes were especially helpful in the study of astronomy. In 1544, a German astronomer, Gemma Frisius, used a pinhole in his darkened room to study a solar eclipse. The image of the Sun was projected on the wall so that he could view it safely. You don't need to use an entire room to make a pinhole projector. Any box with a tiny hole in one end will do. Remember that your image will not be as sharp as an image that passes through a lens. A lens focuses and directs light rays; a hole only lets them in. □

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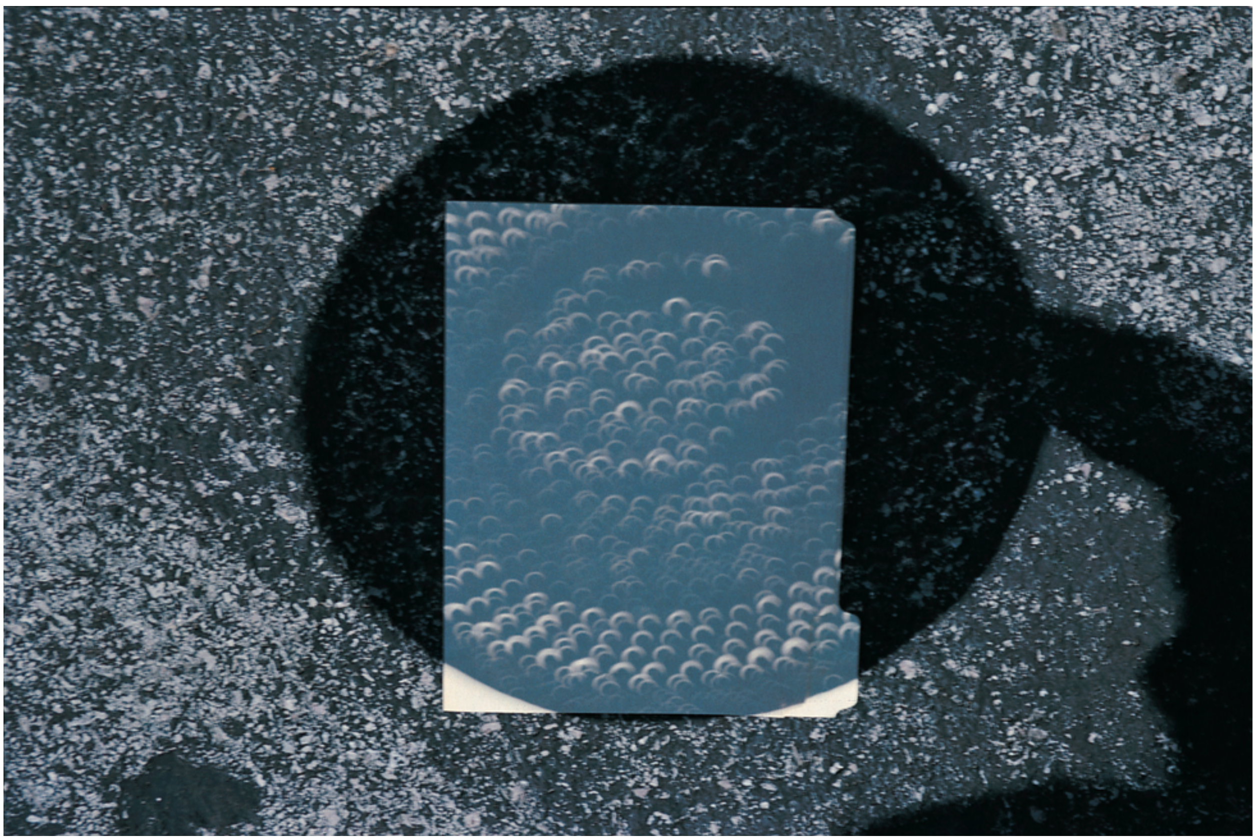
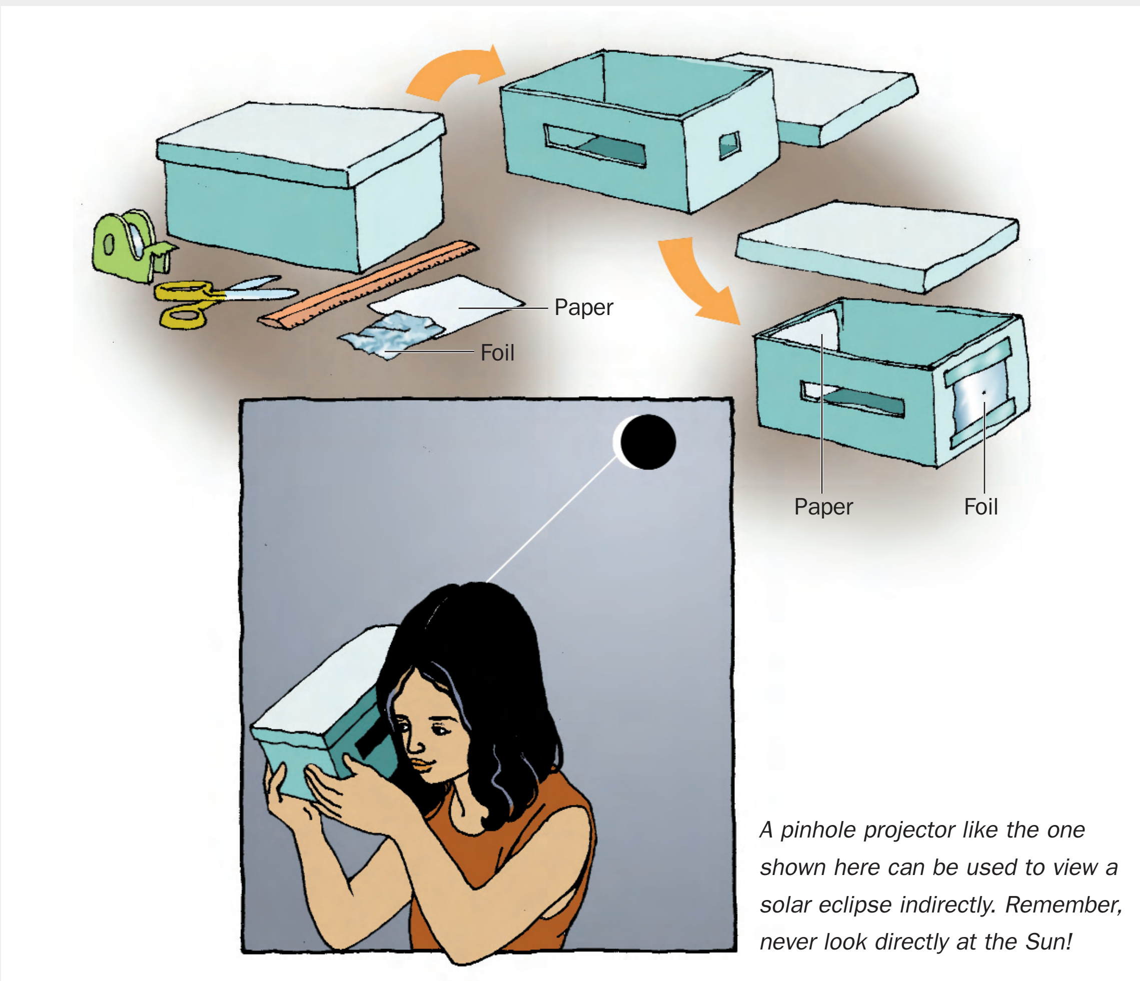


The openings between the holes of a straw hat work like tiny pinholes. This photo shows hundreds of projected images of the annular eclipse seen in the United States on May 10, 1994.

Making a Pinhole Projector

How can you make a small pinhole projector? Follow the steps outlined below:

1. Collect a box (a shoebox with a lid works well), ruler, clear tape, scissors, foil, and white or black paper.
2. Cut out a 2.5-cm square opening at one end of the box.
3. Cut out a 2.5- × 10-cm opening on the side of the box (see the illustration).
4. Tape a piece of foil over the square opening at the end of the box.
5. Make a pinhole right in the center of the foil over the opening.
6. Tape or glue a piece of white (or black) paper on the inside of the box. This paper should be placed opposite the pinhole and serves as a projection screen.
7. Tape the lid onto the box, and make certain there are no areas where light can get in other than through your cut openings.
8. Stand with your back to the Sun and look through the side opening at the white paper. You should see the Sun's image projected onto the screen. You can use this projector to view a solar eclipse.



A pinhole projector like the one shown here can be used to view a solar eclipse indirectly. Remember, never look directly at the Sun!