National Aeronautics and Space Administration

NASA CONNECT™

Path of Totality: Measuring Angular Size and Distance©

An Educator Guide with Activities in Mathematics, Science, and Technology

Educational Product	
Educators	Grades 6-8

EG-2006-02-01-LARC

www.nasa.gov

NASA CONNECT™, *Path of Totality: Measuring Angular Size and Distance*© is available in electronic format. Find a PDF version of this educator guide at the NASA CONNECT™ web site: **http://connect.larc.nasa.gov**

NASA CONNECT™ is produced by NASA's Center for Distance Learning, a division of the Office of Communications and Education at NASA Langley Research Center, Hampton, VA, and is a collaborative endeavor of NASA with the organizations below. NASA's Center for Distance Learning is operated under cooperative agreement. Use of trade names does not imply endorsement by NASA.

PARTNERS

National Institute of Aerospace

www.nianet.org

VirginiaTech

www.vt.edu

AIAA Foundation

www.aiaa.org

Knowitall.org

http://knowitall.org

ibiblio

www.ibiblio.org

Apple Learning Interchange

http://ali.apple.com

NCTM

www.nctm.org

NASA CONNECT™

Path of Totality: Measuring Angular Size and Distance©

An Educator Guide with Activities in Mathematics, Science, and Technology

Program Overview

Hands-On Activity

AIAA FOUNDATION Registered users of NASA CONNECT™ may request an American Institute of Aeronautics and Astronautics (AIAA) classroom mentor. For more information or to request a mentor, e-mail **nasaconnect@aiaa.org**.

Acknowledgements

Special thanks to:

- Summer 2005 Educators in Residence:
  Josephine z , Virginia Beach Public Schools
  Suzanne Sprague, Hampton City Schools
- National Council of Teachers of Mathematics (NCTM)
- Dr. David Pugalee, University of North Carolina, Charlotte
- NASA's Sun Earth Connection Education Forum, Goddard Space Flight Center
- Chris Giersch, Communications and Education Lead, Exploration Systems and Space Operations Technology Directorate, NASA Langley Research Center
- Becky Jaramillo, Program Manager, IPA: Norwood Elementary School, Peoria, Illinois

Program Overview
SUMMARY AND OBJECTIVES

In NASA CONNECT™, *Path of Totality: Measuring Angular Size and Distance©*, students learn about the natural phenomena that create a total eclipse. Students also explore the history, mythology, science, and math that relate to these amazing events. NASA scientists and engineers introduce a satellite where scientists make artificial eclipses in order to learn more about the Sun's corona. Using hands-on lessons, web-based activities, and simple tools, students will measure the angular size and predict the angular distance of objects in the sky.

Student Involvement

Inquiry-Based Questions

Host, Derek Wang, NASA engineers and scientists will pose inquiry-based questions throughout the program. These questions allow the students to investigate, discover, and think critically about the concepts being presented. When viewing a videotape or DVD version of NASA CONNECT™, educators should pause the program at the designated segments so students can answer and discuss the inquiry-based questions. During the program, an icon will appear on the screen to indicate the appropriate time to pause the tape or DVD.

Teacher note: *It is recommended that you preview the program before introducing it to your students so you will know where the pause points occur.*

Hands-On Activity

The hands-on activity is teacher-created and is aligned with the National Council of Teachers of Mathematics (NCTM) Standards, the National Science Education Standards (NSES), the International Technology Standards of Education (ITEA), and the National Educational Technology Standards (NETS). Students use triangles and proportions to create a shoebox eclipse simulator. They apply what they learn about angular size to predict the diameter and distance of one object that can be eclipsed by another.

Squeak Pyramid Challenge

Thales of Miletus (624 to 547 BC) may have been the first person to use geometry to determine the height of pyramids. In this interactive web activity using Squeak, students determine the heights of their simulated pyramids by applying the geometry of similar triangles used by Thales. Students measure three side lengths of two triangles and use ratios to calculate the height of the pyramid. The students can then directly measure the height to check their calculations and measurements.

Resources

Teacher and student handouts enhance and extend the NASA CONNECT™ program. Books, periodicals, videos, and web sites provide teachers and students with background information and extensions.

Background

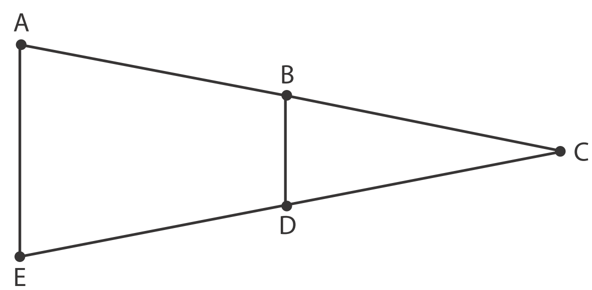
A solar eclipse occurs when some portion of the Sun's disk is covered or eclipsed by the Moon. The path of the Moon must be between the Earth and the Sun.

The most common kind of solar eclipse is a *partial eclipse*. Only the faint outer portion of the Moon's shadow, the *penumbra*, strikes Earth. The center of the Moon does not pass directly over the center of the Sun. In this case, a large portion of the Sun can still be seen. However, when the Moon lines up directly between the Earth and Sun, the Moon's dark inner shadow, the *umbra*, sweeps across Earth's surface creating *a total eclipse* of the Sun. The track of the Moon's shadow across Earth's surface is called the *Path of Totality.* This path is typically 16,000 kilometers (about 10,000 miles) long but only 160 kilometers (100 miles) or so wide. In order to see the Sun totally eclipsed by the Moon you must be in the path of totality.

But other factors play an important role in solar eclipses. Both the Earth and the Moon have orbits that are slightly elliptical, or oval, in shape. The Earth orbits around the Sun and the Moon orbits around the Earth. The plane of the Earth's orbit is referred to as the ecliptic plane. The *ecliptic* is the apparent path the Sun seems to take as the Earth is actually revolving around the Sun. The Moon's orbit is tilted at about five degrees to the Earth's ecliptic plane so the Moon usually passes above or below the direct line of sight between the Earth and the Sun. The Moon's orbit intersects the ecliptic plane at only two points or *nodes*. For a solar eclipse to occur, the Moon must be in a New Moon phase and the New Moon must be close enough to the ecliptic plane (near the nodes) so the Moon's shadow will touch some part of the Earth.

A unique relationship exists between the Sun and the Moon. The Sun is 400 times larger than the Moon, but it is also 400 times farther away creating the illusion that the two objects are the same size. This apparent size, called *angular size*, varies depending on the distances these objects in space are away from the Earth and the relationship of the size of the objects to each other. Imagine extending lines from your viewpoint on Earth to each side of the Sun's diameter. A triangle would be formed. Now imagine extending lines from your viewpoint on Earth to each side of the Moon's diameter. Another similar triangle would be formed. The angle from your viewpoint for both triangles is the same and the sides of these imaginary triangles are proportional. The Sun and the Moon have the same angular size, so the Moon is able to eclipse or cover the disk of the Sun when the Moon is directly between the line of sight of the Earth and the Sun.

$\triangle ACE \simeq \triangle BCD$

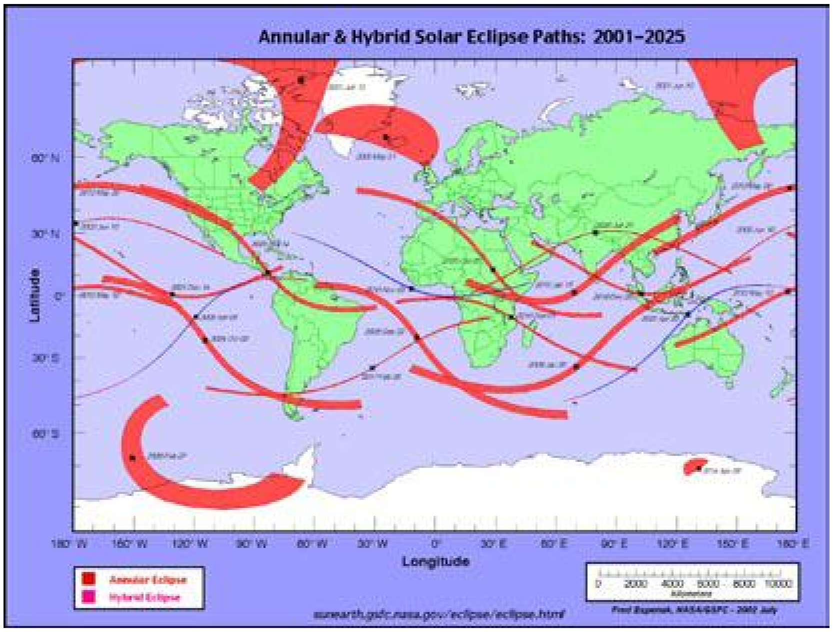


Many objects cross the paths of other objects in the sky, creating eclipses. In some cases, moons have angular sizes that are much larger than the Sun. In other cases, the moons are much too small to cover the Sun. Scientists call this kind of event a *transit*.

The Moon does not always appear to be precisely the same size in the sky as the Sun. The slightly elliptic orbits of the Moon and the Earth affect the angular size of these objects. When the Moon is farthest from the Earth in its orbit, the greater distance between the Moon and Earth prevents the Moon from blocking all of the Sun from view. As the Moon passes directly between the Earth and the Sun, a bright ring of the Sun remains. This is known as an *annular eclipse*.

Total eclipses are rare events, occurring somewhere on Earth approximately once every 18 months. They may recur in any given place only once every 300-400 years. (See map of eclipse paths on page 7.)

http://sunearth.gsfc.nasa.gov/eclipse/SEcat/SEdecade2001.html



Eclipse Predictions by Fred Espenak, NASA's GSFC

Although they last only a few minutes, total eclipses of the Sun are widely regarded as one of nature's most awe inspiring spectacles. As totality approaches the western sky, the chill and sweep of the Moon's shadow rushes across the landscape at over 1600 kilometers (1000 miles) per hour. The darkness of totality resembles nighttime. Birds start singing and many go back to their nests. Daytime flower blossoms begin to close as if for the night, and the temperature drops in the coolness of the Moon's shadow. The sky near the horizon still appears bright with a slight reddish glow and unusual shadow effects. Because the direct light of the Sun is blocked, some of the brighter stars and planets become visible. Tiny specks of light called, "Bailey's Beads" appear spaced irregularly around the disappearing edge of the Sun, forming the appearance of a string of beads around the dark disk of the Moon. When a single point of sunlight remains, a beautiful "diamond ring" effect is created against the outline of the Moon. As the Sun's bright face is replaced by the black disk of the Moon, a beautiful halo surrounds the Moon. This halo is actually the Sun's corona, a super heated plasma two million degrees in temperature, that is visible only during a total eclipse because the light from the Sun's surface overwhelms the much weaker light from its corona. People from many cultures developed myths and legends to explain this mystifying event. The ancients feared that the Sun was abandoning the Earth. The word "eclipse" actually comes from the Greek work meaning "abandonment."

Scientists have used solar eclipses as an important research tool for hundreds of years. Eighteenth century astronomers routinely monitored eclipses to refine the orbits of the Moon and the Earth. In the early 20th century, solar eclipses provided crucial tests of Einstein's theory of relativity. Eclipses are also used to precisely measure the Sun's diameter and to determine if it is changing in size. Biologists and zoologists sometimes use eclipses to study the circadian rhythms of living creatures. Modern science can now predict eclipses with very high precision (to less than a second).

Eclipse observers may find it very tempting to look directly at a solar eclipse because it is not as bright as looking at the full sun. **Looking at any solar eclipse without the proper equipment can cause serious eye damage**. Ordinary dark goggles or sunglasses are not suited for eclipse viewing. Viewing a projection of the eclipse or using special viewing filters is the safest way to watch a solar eclipse.

Instructional Objectives

Students will

- make simple measurements to determine indirect measures.
- make and test conjectures about the relationship between side length and angle measure in triangles.
- measure an angle using a protractor.
- solve problems that involve the use of proportions.
- create a model of a solar eclipse.
- understand how the distance away from the viewer affects the angular size of an object on Earth and in space.
- explain the conditions necessary for a solar eclipse to occur.
- use appropriate data gathering techniques and clearly communicate ideas.

National Standards

NCTM Mathematics Standards:

Numbers and Operations

- Understand meanings of operations and how they relate to one another.
- Compute fluently and make reasonable estimates.

Algebra

- Represent and analyze mathematical situations and structures using algebraic symbols.
- Use mathematical models to represent and understand quantitative relationships.

Geometry

- Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.
- Apply transformations and use symmetry to analyze mathematical situations.
- Use visualization, spatial reasoning, and geometric modeling to solve problems.

Measurement

- Apply appropriate techniques, tools, and formulas to determine measurements.

Data Analysis and Probability

- Develop and evaluate inferences and predictions that are based on data.

Communication

- Organize and consolidate their mathematical thinking through communication.
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.
- Analyze and evaluate the mathematical thinking and strategies of others.
- Use the language of mathematics to express mathematical ideas precisely.

Connections

- Recognize and apply mathematics in contexts outside of mathematics.

NSES Science Standards:

Unifying Concepts and Processes

- Evidence, models, and explanation
- Change, constancy, and measurement

Science as Inquiry

- Abilities necessary to do scientific inquiry

Understanding about scientific inquiry

- Earth and space science
- Earth in the solar system

Science and Technology

- Abilities of technological design

Understandings about science and technology

- Science in personal and social perspectives
- Science and technology in society

History and Nature of Science

- Science as a human endeavor

ITEA Technology Standards of Education:

The Nature of Technology

- **Standard 1:** Students will develop an understanding of the characteristics and scope of technology.
- **Standard 3:** Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- **Standard 6:** Students will develop an understanding of the role of society in the development and use of technology.
- **Standard 7:** Students will develop an understanding of the influence of technology on history.

Design

- **Standard 9:** Students will develop an understanding of engineering design.

The Designed World

- **Standard 17:** Students will develop an understanding of and be able to select and use information and communication technologies.

NETS Standards:

Basic Operations and Concepts

- Students demonstrate a sound understanding of the nature and operation of technology systems.
- Students are proficient in the use of technology.

Technology Productivity Tools

- Students use technology tools to enhance learning, increase productivity, and promote creativity.
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative work.

Technology Communications Tools

- Students use telecommunications, collaborate, publish, and interact with peers, experts, and other audiences.
- Students use a variety of media and formats to communicate information effectively to multiple audiences.

Technology Research Tools

- Students use technology to locate, evaluate, and collect information from a variety of sources.
- Students use technology tools to process data and report results.

NASA Relevance

The Sun is the only star close enough to have real and dramatic effects on our life here on Earth. Improving our observations and our understanding of the Sun-Earth connection brings about beneficial applications. Solar eclipses enable NASA scientists to accurately measure the diameter of the Sun and to search for changes in its diameter over long periods of time. Total solar eclipses allow the observation of structures of the solar corona that cannot usually be studied due to the higher normal brightness of the Sun's surface. The study of the solar corona gives scientists a great deal of information about the Sun's surface and its global variations. The Earth is surrounded by the escaping ionized outer atmosphere of the Sun, known as solar wind. These winds interact with the Earths magnetic field, or magnetosphere, creating solar storms. Space weather disturbances are caused by two common solar storms: solar flares and coronal mass ejections or CMEs. These magnetic storms can interfere with radio, television, and telephone signals, upset the navigation systems of ships and airplanes, and cause electrical blackouts. Sun-induced storms can damage satellites and spacecraft. On a more positive note, solar winds also cause the Aurora Borealis, known as the northern lights. Explosions of material from the Sun's upper atmosphere are hard to see except during total solar eclipses. NASA launches satellites such as SOHO, Solar and Heliospheric Observatory, to study the Sun 24 hours a day, 365 days a year without interruption. The spacecraft uses 12 scientific instruments, including a coronagraph which creates an artificial eclipse, to collect information about the Sun, ranging from activity in the Sun's corona to vibrations deep in the Sun's interior. NASA studies historical eclipse reports and documents, comparing this information to the new data and discoveries made from studying eclipses using the latest technology in order to better understand long term solar magnetic changes.

Preparing for the Activity

Student Materials (per group)

1 standard size shoebox with lid
1 skewer stick
1 piece of black card stock
1 piece of card stock (any color except black)
butterscotch candies (one for each student)
tape
scissors
straight pins or thumb tacks
flashlight
protractor
compass
pencil
calculator
journal

Vocabulary

angular size - measure of an angle formed by extending imaginary lines outward from our eyes to span an object; apparent size of two objects dependent on actual size and distance from the viewer

annular eclipse - an eclipse that occurs when the Moon is directly between the Sun and the Earth and is at the farthest point from Earth in its orbit so that the disc of the Moon does not appear large enough to cover the entire Sun

celestial mechanics – mathematical calculations of the movements and positions of planets and other objects in the sky

corona – the Sun's outer atmosphere that looks like a halo of light around the Sun and is visible only during a total eclipse

Coronal Mass Ejections (CMEs) – large eruptions of plasma from the Sun's corona that extend into space

eclipse – an event when one celestial body crosses the path of another object blocking all or part of the object from view

new moon - the phase of the Moon occurring when it passes between the Earth and the Sun and is visible only as a narrow crescent at sunset

penumbra – faint, outer shadow of the Moon

solar eclipse – the passing of the Moon between the Sun and the Earth that blocks the light of the Sun

total eclipse – an eclipse that occurs when the Moon completely blocks the light of the Sun from reaching Earth because the Moon is directly between the Sun and the Earth

transit – event when one celestial body crosses in front of another

umbra – dark, inner shadow of the Moon

Time for Activitiy

30 minutes for NASA CONNECT™ show
100 minutes for Engage and Explore
300 minutes for Challenge

The Activity

Brief Lesson Description

Students create an eclipse viewer. The students simulate a total eclipse by making a model that uses the diameters of circles and proportional reasoning to determine where to place an object.

Assign Journal Write # 1:

Tell what you know about eclipses. Be specific. Discuss why eclipses occur and how often we experience eclipses. Include a concept map or other graphic organizer.

Technology Insertion Point: *If students have access to Inspiration© or some other graphic organizer program, encourage them to complete their thoughts in a computer-generated chart which can later be easily modified.*

Video Component

View NASA CONNECT™, *Path of Totality: Measuring Angular Size and Distance©* and answer all inquiry-based questions.

Engage

Draw three different circles on the board. Make the first circle small and label it "A". Make the second one larger and label it "B". Draw a very large third circle and label it "C". Ask the students which circle is the largest? Give students more information about the circles. Tell them that A is a distant star larger than our sun, B is the Moon, and C is a weather balloon. Now which would you say is the largest? What factor(s) would cause these objects to appear the size they have been drawn?

Give each student a butterscotch candy disc. Save the yellow cellophane wrappers on the candies as students will use them later. Cut a large circle out of brightly colored paper and tape it on the wall at the front of the classroom. Ask the students to work in pairs. One student should hold the candy at arm's length and move forward or backward until he or she is able to completely cover the object at the front of the room. The other student should measure the distance from the candy to the object on the wall. Record the distance. What happens when the student moves closer to the object? farther away from the object? Ask students to write their observations in their journals.

Discuss the following questions:

1. The candy is much smaller than the object on the wall. Why does the candy appear to cover the object?
2. What happens as you move closer to the object? farther away?
3. Why do you think this happens?
4. What do you know about solar eclipses? Why do you think eclipses occur?
5. How often do solar eclipses occur?
6. What is the difference between a partial eclipse and a total eclipse?

Teaching note: *Students may write their responses in journals and/or discuss them orally. You may wish to post student responses on chart paper or on the board so they can be discussed after the completion of the activity and any misconceptions can be addressed.*

Explore

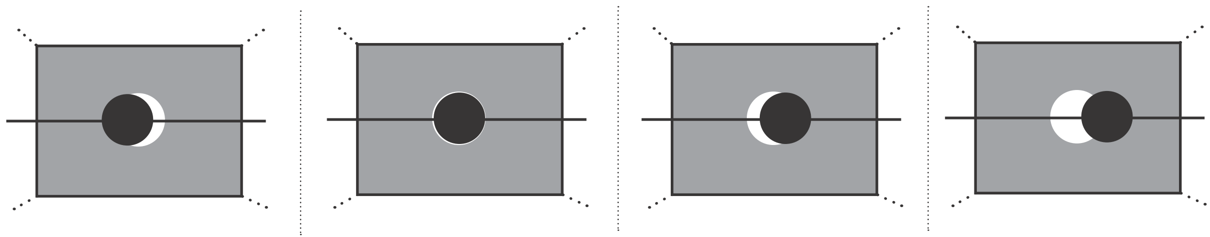
Students will create their own eclipse simulator using a shoebox, a skewer stick, and paper circles. See Student Handout for directions.

Assign Journal Write # 2

Explain what you saw when you made your eclipse simulator. How is your model similar to an actual eclipse? How is the model different?

Explain

Students should be able to look into the viewers and see a model of a solar eclipse. The smaller circle cut-out should appear to be the same size as the larger circle cut-out. Students may slide the skewers back and forth in order to see how the Moon moves to cover up our view of the Sun.



Teaching Note: *Make sure that when students look through the peep-hole, they put their eye as close to the hole as possible.*

Discuss the following questions.

1. What are two reasons why looking at objects in space is different than looking at objects in your classroom?

   In space we may not know how far away the object is. In space we may not know how large the object is. In the classroom we use short distance vision, which allows us to use our depth perception. When looking at objects in space we do not have the ability to use depth perception because the objects are too far away. Scientists use their understanding of similar triangles to help them calculate the distance of objects in space.

2. What factors determine how large objects in space appear?

   Factors include the distance the object is away from you and its size.

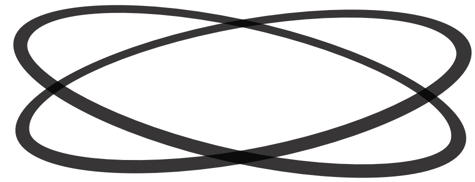
3. Describe what occurs during a solar eclipse.

   The Moon passes in front of and covers our view of the Sun. As a result, the Moon casts a shadow on the Earth for a short time until the Moon is no longer blocking our view of the Sun.

4. How is angular size important when determining whether or not a solar eclipse can occur?

   Even though the Sun is about 400 times larger than the Moon, its angular size from Earth is the same because it is also 400 times further away from the Earth than the Moon. Therefore, the size of the Sun and the Moon appear about the same in the Earth's sky. When the Moon's orbit around the Earth takes it directly between the Sun and the Earth, the Moon can obscure all or part of the Sun, causing a solar eclipse. If the Moon's angular size were much smaller than the Sun's angular size, its shadow would not be large enough to cause an eclipse.

Teaching note: *Go back to the original engage questions and ask students to evaluate their responses. Were any of their responses inaccurate? Ask students to write what they know now in a different color ink. You may wish to address misconceptions about the frequency of eclipses and the tilt of the Earth's orbital plane by conducting this simple demonstration.*



Hold up two hula hoops. Place one hula hoop inside the other so they intersect. Tilt one hoop about five degrees. Both hoops should be fully visible. Explain that these hoops represent the orbital paths of the Earth and the Moon. Point to the place on each side where the two hoops intersect. The points where the Moon's orbit intersect the geometric plane of the Earth's orbit are called the nodes. Discuss, then, why total solar eclipses are so rare. Remind students that the Earth and Moon are not only revolving or orbiting around the Sun, each is also rotating on its own axis. Because these orbital periods are not the same, the Moon is not always in the New Moon phase when it crosses the nodes each time.

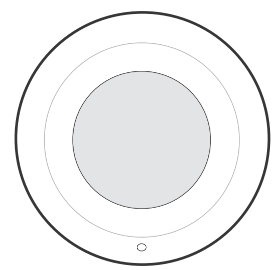
Assign Journal Write # 3

Revisit your understanding of eclipses. Explain what you now know about eclipses and why they occur. If you included a concept map or other graphic organizer, add your new ideas in a different color ink.

Extend

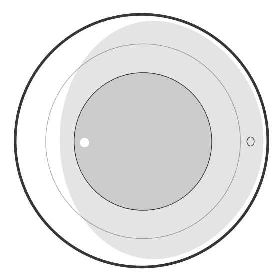
1. Tape a piece of yellow cellophane over circle A on your eclipse viewer. Put on a pair of dark sunglasses. Ask a partner to shine the flashlight directly into circle A. Be sure your skewer stick and circle B are still in the correct location to simulate an eclipse. Look through the peep-hole. Describe what you see. How is this like the corona visible during a total eclipse?

2. Using the NASA JPL Solar System simulator, compare the views of different objects in space from various planets and space objects. Adjust the field of view to get the largest image possible. You may need to try several different settings. Select a planet and view it from each of its moons. Create a work of art that shows what the planet would look like from each viewing point. Be sure to label the planet and each moon. **http://space.jpl.nasa.gov/**



3. Do research on ancient myths about Solar Eclipses using books, the Internet, and other resources. Choose one myth and create a comic strip that shows how the myth explains what happens during an eclipse. Write your own eclipse myth.

4. Conduct some research about lunar eclipses. Design a model that illustrates a lunar eclipse. Describe the differences between solar and lunar eclipses and be sure your model clearly demonstrates these differences.



5. Make your own Shadow Bowl to watch the apparent path of the Sun. Punch a hole in the side of a paper bowl using a paper punch. Fasten the bowl to a stake and put the stake in the ground. Tilt the bowl up so the sunlight shines through the hole. Do not look at the Sun. You will be able to see the dot of light travel across the surface of the bowl at different times of the day. Keep a record of the position of the dot and the time of the day. What can you learn about the ecliptic from watching the dot?

Technology Insertion Point: *Have students visit Daniel Oberti's web site to find out more about shadow sculptures. Create a multi-media presentation to showcase Daniel's sculptures. Add captions that explain the science and/or math behind each sculpture. Students may wish to add music to the presentation.*

http://www.danieloberti.com/

Evaluate

Create a rubric that assesses the students' measurements and calculations, creation of the solar eclipse viewer, and answers to questions.

Ask students to use their eclipse simulators to demonstrate a partial eclipse, an annular eclipse, and a total eclipse.

Assess students' journal responses for an increase in content knowledge and for self-correction of misconceptions.

Challenge

Ask advanced students to prove or disprove the statement:

"In our solar system, total solar eclipses are visible no where other than on Earth."

Students should conduct research to collect the data for the Eclipse chart. Use the data to set up proportions.

Technology Insertion Point: *Students may find the information they need to complete the chart at the following web sites:*

NASA Solar System Lithographs

http://www.nasa.gov/pdf/58275main_Solar.System.Lithograph.Set.pdf

NASA Solar System Exploration

http://solarsystem.nasa.gov/planets/profile.cfm?Object=Earth

Students will determine whether or not the relationships between the Sun and moons from other planets are proportional to the distance from the Sun to that planet by calculating the ratios. If the ratios are similar *(they do not need to be exact)*, a total eclipse is possible.

Example: Earth

$$\frac{3{,}476 \text{ km } \textit{(diameter of the Moon)}}{384{,}400 \text{ km } \textit{(distance from Earth to Moon)}} = \frac{1{,}391{,}000 \text{ km } \textit{(diameter of the Sun)}}{149{,}600{,}000 \text{ km } \textit{(distance from Earth to Sun)}}$$

Students may evaluate the ratios in different ways, but should be able to explain in writing how they determined whether or not the numbers are proportional and whether or not an eclipse is possible. Some students may extend the use of their eclipse box or develop a model similar to what was done with the butterscotch candies in the Engage section to justify their calculations. Students should then compile their findings and make recommendations about which planets, if any, may be the best places to view other solar eclipses. Students may also wish to consider whether any other objects in the sky, either natural or man-made, have the same angular size as the Sun thus creating a solar eclipse. Reports may then be submitted to the NASA CONNECT™ Challenge at http://connect.larc.nasa.gov/.

Student work should be assessed using the following criteria:

- Students effectively set up proportions.
- Students provide written explanation of how they solved the proportions.
- Students evaluate the possibility of an eclipse.
- Students create a model to prove their calculations.
- Students present their findings in a multi-media format that clearly communicates their findings.

Teaching note: *Some students may want to calculate the angular size of these objects in degrees. A simple change in the proportion will allow them to do this.*

$$\text{angular size (degrees)} = \frac{57.3 \bullet \text{diameter of object (km)}}{\text{distance of object to Sun (km)}}$$

Astronomers use this formula to compare the size of objects at a great distance. Both degrees and radians measure arcs, or segments of a circle. In this case, the angle in radians is the diameter of the object divided by the distance of the object from the Sun. In a full circle, there are 360 degrees, or 2 π radians. One radian is equal to 57.3 degrees. The angular size of the Sun and full Moon is equal to 0.5 degrees.

Student Handout
ECLIPSE SIMULATOR DIRECTIONS

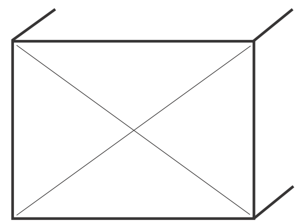
1. First trace the lighted end of a flashlight onto a piece of card stock. Cut out that circle and label it "A."

2. Next trace a quarter on a piece of black card stock. Cut out the circle and label it "B."

3. Using your metric ruler, measure the diameter of both circles. Record the measurements in your journal.

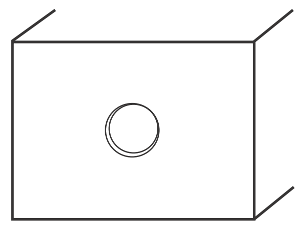
4. Find the center or midpoint of circle A. *(You may fold the circle into fourths. The point where the lines intersect is the center or midpoint.)*

5. Find the geometric midpoint of each end of the shoebox. *(Make sure the box is the same size on both ends.)* You may use string or a ruler to find the diagonals of the shape. The center of the rectangle is the point where the diagonals intersect. Verify your midpoint by measuring.



Step 5

6. Using a stick pin, line up the center of circle A on the midpoint of one end of the shoebox. Trace the circle onto the shoebox. Carefully cut out the circle so the box now has an open circle in one end. Your open circle will now be circle A.



Step 6

7. On the opposite end of the shoebox, make a hole approximately 2 cm in size. The shape of the hole is not important, but the hole should be centered on the midpoint you marked earlier. This will be your peep-hole, so be sure you have no jagged edges that could poke your eye.

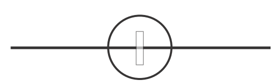
8. Measure and record the distance from the peep-hole end of the box to the opposite end of the box where you cut out circle A. Record this measurement in your journal. Be precise when you measure.

9. Draw a horizontal line through the middle of each side of the shoebox. The line should be drawn along the entire length of the box to the other. Be sure to measure carefully and make your line straight.

10. With the help of an adult, make a slot along these lines on both sides of the box using a utility knife. The slots should be wide enough to allow your skewer stick to move freely when slipped into the slots.

Step 10

11. Tape circle B, which you cut out of the black construction paper, to the center of a skewer stick.



Step 11

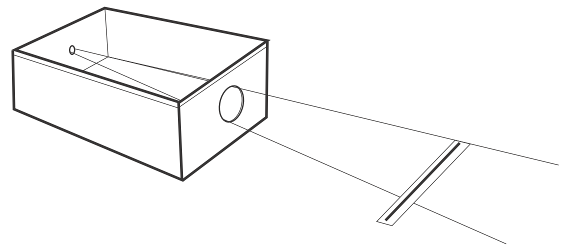
12. Determine where you should place circle B in the box in order to eclipse circle A. Use this proportion to calculate the distance from the peep-hole to the smaller circle.

$$\frac{\text{Diameter of the larger circle}}{\text{Distance from peep-hole to larger circle}} = \frac{\text{Diameter of the smaller circle}}{\text{Distance from peep-hole to the smaller circle}}$$

ECLIPSE SIMULATOR DIRECTIONS

Student Handout

Activity Directions Part 2:



You already know the diameter of both circles and the distance from the peep-hole to the larger circle. Solve for your unknown distance.

For example:

If the diameter of circle A is 8 cm and its distance from the peep-hole is 24 cm, and the diameter of circle B is 2 cm, you would set up a proportion to solve for the unknown distance.

$$\frac{8\text{ cm}}{24\text{ cm}} = \frac{2\text{ cm}}{x}$$

In a proportion, the product of one numerator and the other denominator is a cross product. First you will need to identify the cross products and multiply them:

$$24 \bullet 2 = 48$$

$$8 \bullet x = 8x$$

If two ratios form a proportion, the cross products should be equal. Write a number sentence to show this equality.

$$48 = 8x$$

To solve for x, divide both sides of the equation by the cross product of x. *(The cross product will be the number in front of the x.)*

$$\frac{48}{8} = \frac{8x}{8}$$

$$x = 6\text{ cm}$$

Your skewer stick, with the smaller circle attached, should be placed in the slot 6 cm from the peep-hole to eclipse the larger circle.

Student Handout
Activity Directions Part 3:

13. Following step 12, calculate and record the distance you think your skewer stick should be placed from the peep-hole.

14. Place your skewer in the slots at the position you calculated. Place the lid back on the shoe box. Be sure the skewer stays in place.

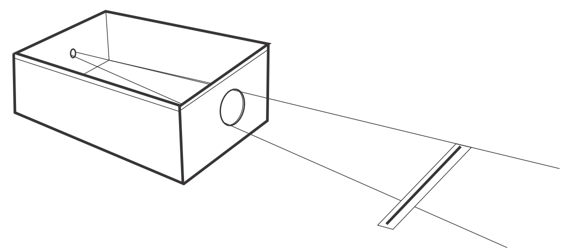
15. Look through the peep-hole to see if your calculations are correct. Does the smaller circle cover the larger circle? Why do you think this happens? Stop and discuss with a partner. If your smaller circle does not eclipse the larger circle, check your calculations and measurements again.

16. Move your skewer stick slightly forward and backward along the slots. Does the smaller circle still eclipse the larger circle? Why or why not? Discuss with a partner.

17. As you continue to look through the peep-hole, move your skewer slowly from side to side. In your journal, record what you see happening.

Student Handout
INVESTIGATING ANGULAR SIZE

Let's investigate to find out why a smaller object is able to completely eclipse a larger object.



1. Cut two pieces of string one meter in length.
2. Remove the lid from the shoe box.
3. Tie one end of each piece of string together and tape the knot to the bottom of the peep-hole.
4. Run the string through the box and tape one string to each side of circle B. You will have several centimeters of string left over. Just leave it on the outside of the box for now.
5. Look at the shape the string forms. What shape do you see? Draw a picture of what you see in your journal.
6. Triangles have special characteristics. The sides of a triangle always stay in proportion. Triangles that have the same shape, but are not necessarily the same size, are known as similar triangles. Two figures are similar if their matching angles have the same measure and their matching sides are proportional.
7. Use a protractor to measure the small angle at the vertex near the peep-hole. Record this measurement.
8. Multiply the distance to circle A by 2. Record this number.
9. In your journal, make some predictions about the diameter of an object that circle B could eclipse at the new distance.
10. Cut-out circle "C" using the diameter you determined in step 9.
11. With a partner, extend the strings to their full length, keeping the strings straight and keeping the sides of the triangle in proportion.
12. Use your metric ruler to measure the distance you recorded in step 8. Start at the peep-hole, measuring the distance on the string. Clearly mark the distance on the string.
13. Place circle C between the strings at the marked point. Do the sides of the circle touch the sides of the string?
14. Use the proportion formula to verify your results.
15. What is the relationship between the distance of the two objects and the diameter of the two objects?
16. Did the measure of the vertex angle near the peep-hole change for this new triangle? Why or why not?
17. Use what you have learned about the sides of similiar triangles to predict the diameter of an object that is 75 cm from the peephole. 100 cm. Verify your predictions.
18. Complete Journal Write # 2.

Student Handout
Journal Write

Journal Write #1
Tell what you know about eclipses. Be specific. Discuss why eclipses occur and how often we experience eclipses. Include a concept map or other graphic organizer.

Journal Write #2
Explain what you saw when you made your eclipse simulator. How is your model similar to an actual eclipse? How is the model different?

Journal Write #3
Revisit your understanding of eclipses. Explain what you now know about eclipses and why they occur. If you included a concept map or other graphic organizer, add your new ideas in a different color ink.

Student Handout
ECLIPSE DATA CHART

PLANET DATA

Name of Planet	Average Distance from Sun
Mercury	
Venus	
Earth	149,600,000 km
Mars	
Jupiter	
Saturn	
Uranus	
Neptune	
Pluto	

MOON DATA

Planet	Name of the Moon	Diameter of the Moon	Average Distance from Planet to the Moon
Earth	Moon	3,476 km	384,400 km

SUN DATA

Diameter of Sun	1,391,000 km

Resources

Books

Davis, Kenneth: *Don't Know Much about the Solar System.* Harper-Collins Publishers, 2004, ISBN: 0064462307.

Kong, Kelly: *Eclipse.* Pearson Education, 2005, ISBN: 0328139092.

Love, Ann and Jane Drake: *The Kids Book of the Night Sky.* Kids Can Press, Limited, 2004, ISBN: 1553371283.

Macfarian, Allan: *Native American Tales and Legends*. Dover Publications, 2001, ISBN: 0486414760.

Reimer, Luetta: *Mathematicians are People, Too: Stories from the Lives of Great Mathematicians, Volume 1*. Dale Seymour Publications, 1999, ISBN: 0866515097.

Rhatigan, Joe and Rain Newcomb: *Out-of-This-World Astronomy.* Sterling Publishing Company, 2005, ISBN: 1579906753.

Simon, Seymour: *Sun.* William Morrow & Company, 1990, ISBN: 0688092365.

Whitethorne, Baje: *Sunpainters: Eclipse of the Navajo Sun.* Salina Bookshelf, 2002, ISBN: 1893354334.

Web Sites

NASA Eclipse Homepage
http://sunearth.gsfc.nasa.gov/eclipse/eclipse.html

Science at NASA: "There Goes the Sun"
http://science.nasa.gov/newhome/headlines/ast05aug99_1.htm

NASA's Imagine the Universe:
"More about Angular Size"
http://imagine.gsfc.nasa.gov/YBA/HTCas-size/more-ang_size.html

Mr. Eclipse- Eclipse Photography
http://www.mreclipse.com/MrEclipse.html

SOHO Exploring the Sun
http://sohowww.nascom.nasa.gov/

Tracking a Solar Storm
http://son.nasa.gov/tass/index.htm

Solar System Simulator:
Objects in Space from Different Perspectives
http://space.jpl.nasa.gov/

Daniel Oberti: Ceramic Design
http://www.danieloberti.com/

Videos

NASA's Center for Distance Learning: *NASA CONNECT™, Ancient Observatories: Measuring Different Angles* (2005)
Grades 6 – 8

NASA's Center for Distance Learning: *NASA CONNECT™, Venus Transit* (2004)
Grades 6 – 8

Cerebellum Corporation: *Standard Deviants School Astronomy: The Sun* (1997)
Grades 4 - Adult

Disney Educational Productions: *Bill Nye, the Science Guy: The Sun* (1995)
Grades 3 – 8

Sling Shot: *Solarmax (IMAX)* (2002)
Grades 6 – Adult