JOURNEY through the UNIVERSE

Voyage: A Journey through our Solar System

Grades 5-8

Lesson 3: How Far is Far?

On October 17, 2001, a one to ten billion scale model of the Solar System was permanently installed on the National Mall in Washington, DC. The *Voyage* exhibition stretches nearly half a mile from the National Air and Space Museum to the Smithsonian's Castle Building. *Voyage* is a celebration of what we know of Earth's place in space and our ability to explore beyond the confines of this tiny world. It is a celebration worthy of the National Mall. Take the *Voyage* at www.voyageonline.org, and consider a *Voyage* exhibition for permanent installation in your own community.

This lesson is one of many grade K-12 lessons developed to bring the *Voyage* experience to classrooms across the nation through the *Journey through the Universe* program. *Journey through the Universe* takes entire communities to the space frontier.

Voyage and *Journey through the Universe* are programs of the National Center for Earth and Space Science Education, Universities Space Research Association (www.usra.edu). The Voyage Exhibition on the National Mall was developed by Challenger Center for Space Science Education, the Smithsonian Institution, and NASA.

Lesson 3: How Far is Far?

Lesson at a Glance

Lesson Overview

Students will determine the actual distance to the Sun and the Moon without ever leaving the Earth, and in doing so will gain a better understanding of the huge distances in the Earth-Sun-Moon system. In order to determine these distances, students will apply their understanding of mathematical models in two different ways, using a single mathematical principle.

Lesson Duration

Two to three 45-minute class periods

Core Education Standards

National Science Education Standards

Standard A2: Understandings about scientific inquiry

- Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.
- Mathematics is important in all aspects of scientific inquiry.

Standard D3: Earth in the solar system

The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.

AAAS Benchmarks for Science Literacy
Benchmark 2B1:
Mathematics is helpful in almost every kind of human endeavor—from laying bricks to prescribing medicine or drawing a face. In particular, mathematics has contributed to progress in science and technology for thousands of years and still continues to do so.

Benchmark 4A2:
The sun is many thousands of times closer to the earth than any other star. Light from the sun takes a few minutes to reach the earth, but light from the next nearest star takes a few years to arrive. The trip to that star would take the fastest rocket thousands of years. Some distant galaxies are so far away that their light takes several billion years to reach the earth. People on earth, therefore, see them, as they were that long ago in the past.

Essential Question

- How can we use models to measure the relative distances between the Sun, the Earth, and the Moon?

Concepts

Students will learn the following concepts:

- We can use objects like the Sun or Moon, and models of the Sun and Moon, as rulers.
- We can use models to study things that are big, like the Sun or the Moon.
- Similar triangles have angles that are the same and sides that are proportional.
- The distance to the Sun and the Moon can be determined without ever leaving the Earth.

Objectives

Students will be able to do the following:

- Determine the distance to the Sun using a pinhole tube.
- Determine the distance to the Moon using a model of the Moon.
- Use models and similar triangles to explore the Earth-Sun-Moon system.

Science Overview

The brightest objects in the sky are the Sun and the Moon. The Sun creates the daily rhythm for all life forms living on or near the surface of Earth by determining whether it is day or night. The Moon is Earth's celestial neighbor; it is the brightest object in the night sky and sometimes can even be seen during the day. In exploring the cosmic neighborhood of the Earth, it is natural to begin with the Sun and the Moon.

The Sun: The Supreme Ruler of the Solar System

The Sun is at the center of the Solar System. The nine planets and their moons as well as the smaller bodies—such as asteroids and comets—all revolve around the Sun. The Sun's role as the center and supreme ruler of the Solar System comes from its high mass: it has 99.8% of the mass in the system and, therefore, guides the movement of the other objects via gravitational forces. Sunlight brings energy to the rest of the Solar System and largely determines the conditions prevalent at the planets, from making the sunlit side of Mercury bake in 427ºC (800ºF) heat to providing the hospitable environment for life on Earth.

The Sun is a fairly typical star, just one of over 200 billion stars in the Milky Way galaxy. It is not among the brightest or the faintest stars. Even though it is more massive than about 96% of the stars in the Milky Way, there are billions of stars more massive than the Sun. The Sun is made up entirely of gas, mostly of hydrogen (91% of the atoms) and helium (8.9%), with heavier elements such as oxygen, carbon, neon, and nitrogen mixed in to make up the remaining 0.1%. The Sun is powered by nuclear fusion occurring at its center; in this process, hydrogen atoms are converted into helium, with energy released as a by-product.

The Sun's diameter is about 1.4 million km (865,000 miles), roughly 109 times Earth's diameter. This is the same ratio as between the height of an NFL linebacker (185 cm) and the size of a honey bee (1.7 cm). The Sun is about 150 million km (93 million miles) away from Earth. The situation is similar to the honey bee hovering about two football fields away from the linebacker. The mass of the Sun is 1.99×10^{30} kg, or about 333,000 times Earth's mass. This is the same ratio as between a linebacker (100 kg) and three honey bees (0.1 g each).

When the Sun is observed with instruments (the Sun should never be looked at directly), it appears to have a surface (see Figure 1). But since the Sun is made entirely of gas, it does not have a solid surface like Earth does. Instead, the apparent surface of the Sun is the region

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where the light that can be seen starts its journey into space and where the visible solar features appear. The behavior of the features on the Sun's surface is regulated by the Sun's activity cycle, the progression of which can be followed by counting the number of sunspots visible on the Sun's surface. The sunspot number changes from a minimum to a maximum and back to a minimum over the solar activity cycle, with an average period of about 11 years.

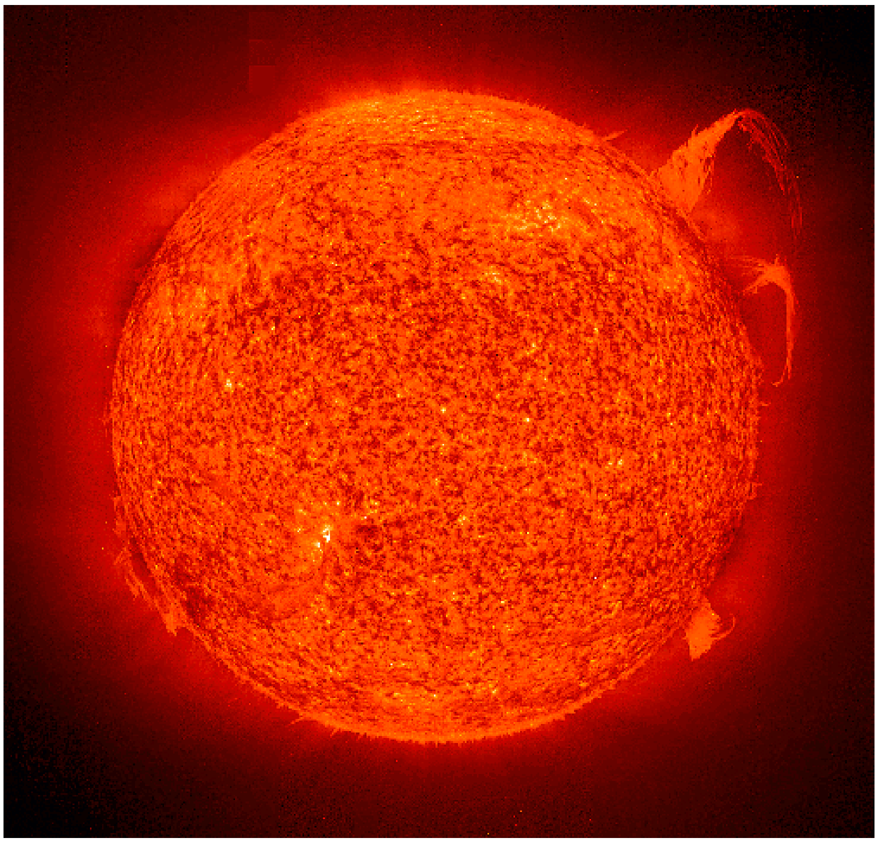

Figure 1: The Sun seen in extreme ultraviolet wavelengths. (Picture credit: NASA/SOHO; http://sohowww.nascom.nasa.gov/bestofsoho/hooksG.gif)

THE LIFE AND TIMES OF THE SUN

The formation of the Sun began when a dense region of a slowly spinning cloud of gas and dust in space began to contract under its own gravity. In the central part of the cloud, an infant Sun was born, and around it, a rapidly spinning disk was formed. The disk fed material onto the growing infant Sun, while at the same time, small dust grains within the disk grew to become planetary building blocks, and eventually whole planets. The temperature inside the developing Sun grew until nuclear fusion, the power process of the stars, began at its center. At this time, about 4.6 billion years ago, the Sun became a young star.

The Sun has been burning hydrogen ever since and has enough fuel for another 5 billion years or so. When the Sun runs out of fuel at its center, its outer layers will expand in the so-called red giant phase of its life, and engulf the orbit of Earth. Later on, the aging Sun will cast off its outer layers in the form of a shell-like planetary nebula, while the remaining parts will become a dense object called a white dwarf. The white dwarf will slowly fade and after a few billion years will become a very faint object called a black dwarf: this will be the final fate of the Sun.

Sun's Effect on Earth

The Sun provides most of the energy on Earth. Without the Sun, the Earth would be cold and lifeless. On Earth, sunlight is absorbed by the ground, the seas, and the atmosphere. It drives air flows in the atmosphere and currents in the oceans, and greatly influences climate and weather. It is the most important source of energy for life on Earth; it provides energy for photosynthesis and, therefore, supports the first link in many of the food chains on Earth. It is possible for life to exist in places without sunlight (such as at the bottom of the oceans), but most of the life with which we are familiar uses the energy provided by sunlight in one way or another.

The fact that the Earth is capable of supporting a wide variety of life forms is due to its distance from the Sun. When objects move farther away from the Sun, they receive less sunlight and their temperatures drop. Earth is at just the right distance from the Sun so that liquid water can exist on its surface. Liquid water is thought to be essential for the existence of life forms, but it is liquid only in a small temperature range, from 0ºC (32ºF) to 100ºC (212ºF), depending on factors such as pressure and impurities in the water. If the Earth were at a different distance from the Sun, it is possible that life would never have developed here!

Earth's orbit around the Sun is nearly circular. That means that its distance from the Sun does not vary much during the year. The average distance from the Earth to the Sun is about 150 million kilometers (or 93 million miles). This is a huge number and even astronomers prefer to use numbers a little more manageable. They have defined the unit for distances in the Solar System to be the average Earth-Sun distance: Astronomical Unit (AU). The closest distance that the Earth gets to the Sun (a point in Earth's orbit called perihelion) is 0.98 AU, and the farthest (called aphelion) is 1.02 AU; the variation in the distance is minimal. The orbits of the other planets in the Solar System are nearly circular, as well, with two exceptions: Mercury and Pluto.

The Moon

The Moon is Earth's celestial neighbor. It is about 384,000 km (239,000 miles) from the Earth, and its diameter is about one quarter of Earth's. By comparison, if a standard-sized (23 cm or 9 in) Earth globe (or a basketball) represents the Earth and a baseball represents the Moon, then the baseball would be 30 Earth diameters (6.9 m) away. Another way to bring the distances to a more manageable scale is to use a one to 10 billion scale model, as is done with *Voyage*, a scale model of the Solar System, located on the National Mall in Washington, D.C. In this case, the distance between the Earth and the Moon is 3.84 cm (1.5 in), Earth's diameter is 1.3 mm (0.05 in), and the Moon's, 0.35 mm (0.01 in). The orbits of the planets closest to Earth (Venus and Mars) would be about 4 m (13 ft) and 8 m (26 ft) away, and the Sun would be located at a distance of about 15 m (49 ft). Compared with the other objects in the Solar System, the Moon is basically just a hop and a skip (or at least a few days' rocket ride) away from the Earth.

It takes the Moon 27 $^1/_3$ days to go once around the Earth. The Moon's distance from the Earth varies during its orbit. The closest approach of the Moon to the Earth (a point in its orbit called perigee) is 363,000 km (226,000 miles), and the farthest point (called apogee) is 405,500 km (252,000 miles): a total distance change of 11% during one orbit. The Moon's orbit around the Earth is much more oval-shaped than the Earth's orbit around the Sun. Consequently, the size of the Moon seen in the sky varies by about 11% during a month–in contrast, the Sun's apparent size in the sky changes by only 3% during a year.

The Moon's composition is very similar to those of Earth and the other rocky, Earth-like planets in the Solar System. In fact, its similar composition to the Earth's crust material was a crucial clue in developing an understanding of its origin. The Moon is thought to have formed when a Mars-sized object smashed into the forming Earth billions of years ago. Material was blasted into orbit around Earth by this collision and later collected together to become the Moon. Exactly how this process occurred is still being investigated.

The surface of the Moon (see Figure 2) is heavily cratered as a result of meteoroid bombardment in the past. Large meteoroid impacts were common in the early history of the Solar System, when the leftover chunks of rocky material from its formation collided with the developing planets and moons. Most solid bodies in the Solar System have heavily cratered surfaces. Sometimes these craters have been filled with lava flows, and traces of most craters on Earth have been erased by geologic activity during the planet's history. But even on Earth, signs of meteoroid impacts from the past are visible; for example, many lakes are originally impact craters that were later filled with water. There are two main types of terrain on the Moon: the old, light-colored, heavily cratered highlands, and the younger, dark, smooth areas called maria.

Figure 2: A computer-generated color picture of the Moon based on data taken by the Galileo spacecraft in 1990. (Picture credit: http://nssdc.gsfc.nasa.gov/imgcat/html/object_page/gal_p37329.html)

Humans on the Moon

The Moon is the only heavenly body that humans have ever visited (as opposed to robotic spacecraft making observations or taking samples). Between 1969 and 1972, six Apollo spacecraft landed on the Moon: Apollo 11, 12, 14, 15, 16, and 17. Apollo 13 had a mishap on its way to the Moon and, after an ingenious rescue effort, returned safely to the Earth, but without making the planned Moon landing. The Apollo missions brought back a total amount of 382 kg of rock samples from the surface of the Moon. Studies of these samples in laboratories here on Earth have revealed lots of information about the composition, the structure, and the history of the Moon.

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Eclipses

Even though the Sun and the Moon are very different in size (Sun's diameter of 1.4 million km; 865,000 miles, vs. Moon's 3,500 km; 2,200 miles), the Moon is so much closer to the Earth than the Sun that the angular size (the angle of the sky they appear to cover) of the two celestial objects as seen from the surface of Earth is the same. This is a manifestation of the optical effect where nearby small objects appear bigger than larger objects farther away (see Figure 3).

As a result of the same angular size of the Sun and the Moon, interaction between these two objects in the sky as seen from the surface of Earth, gives rise to eclipses. On its orbit around the Earth, the Moon may pass in front of the Sun (as seen from the surface of Earth) and cast a shadow on the surface of Earth. Within the shadow, the Moon appears to block the Sun in the sky, giving rise to a total eclipse of the Sun. Nearby regions may be only in partial shadow (that is, only part of the Sun appears to be blocked by the Moon): this event is observed as a partial eclipse. Other parts of the Earth not touched by the Moon's shadow do not observe any eclipse at all. This is because the Moon's shadow covers only a small region on the Earth's surface—at most, 267 km (or 166 miles) across.

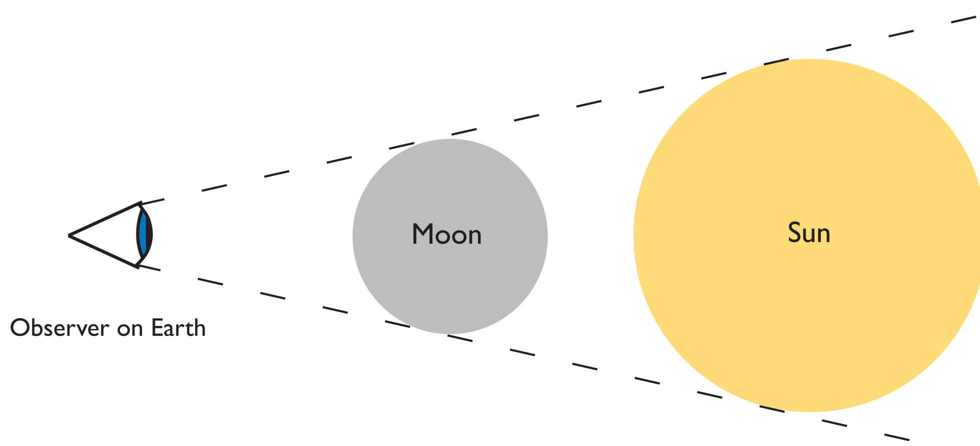

Figure 3. The angular sizes of the Moon and the Sun are the same to an observer on Earth. This is because the Sun, a much larger object than the Moon, is much farther away from Earth. NOTE: Objects and distances in the figure are not drawn to scale. REMEMBER never to look directly at the Sun.

The Moon's orbit may take it through Earth's shadow. A lunar eclipse occurs when the sunlight-illuminated surface of the Moon is shaded by Earth's shadow. Just as with a solar eclipse, a lunar eclipse may be total or partial, depending on whether Earth's shadow covers the whole visible surface of the Moon or just part of it.

Measuring the Distances to the Moon and the Sun

Measuring the distances to the brightest objects in the sky has been a goal for generations of astronomers. For example, ancient Greeks (such as Aristarchus of Samos, 310-230 B.C.) were attempting to measure the distance to the Moon based on the timing of lunar eclipses, and the distance to the Sun based on the phases of the Moon. The results were not very accurate, but the ingenuity of constructing methods to measure these distances in ancient times is admirable. The phases of Venus were used at later times to measure the distance to the Sun.

In modern times, the distance to the Moon has been measured accurately using retroreflectors left behind by the Apollo 11, 14, and 15 missions. Retroreflectors are suitcase-sized devices constructed of mirrors so that they always reflect a light beam back into the direction from which it came. When a laser beam is aimed at the Moon's surface, the devices reflect it back to Earth. Measuring the beam's travel time and using the speed of light gives a distance to the Moon to an accuracy of a few centimeters. The distances to nearby planets can be measured by radar observations: the time it takes for a radio signal to travel to a planet and bounce back to Earth from the planet's surface tells how far the planet is located. Using the distances to the planets derived this way (Venus, for example, is often used for this purpose), the distance to the Sun can be calculated using geometry.

It is relatively easy to get an estimate of the distance to the brightest objects in the sky using their sizes as the basic ruler, but it is very difficult to get accurate results. Scientific measurements have sources of error. One of the goals of repeated measurements and improved techniques is to take these sources of error into account and achieve more accurate results. An understanding of the basic physics that guides the behavior of planets can provide information on their relative distances. Making accurate measurements is much more difficult and requires modern technology.

The situation gets even more difficult when determining distances beyond the Solar System, since there is little hope of taking instruments to make measurements much beyond the Solar System anytime soon. Instead, scientists have to rely on understanding of astronomical phenomena to estimate distances within Milky Way and throughout the Universe. Using this process creates a distance ladder, where measurements of nearby distances are used as a basis on which the next step—going farther—is based. This means that measuring the distances to the cosmic neighbors of the Earth is the first step in understanding the distances between celestial objects. Ultimately, this journey of discovery will lead to determining the distances to stars, distances between galaxies, and ultimately the scale of the Universe.

NOTES:

Conducting the Lesson

Warm-Up & Pre-Assessment

Teacher Materials

- Photograph (See *Preparation and Procedures* for suggestions.)
- Enlargement of the same photograph
- Photograph with objects at different distances

Preparation & Procedures

1. Find a photograph of just one object, in which the picture of the object is much smaller than the actual object. For example, a picture of person is smaller than the real person.

2. Enlarge the photograph on a copier so that the picture of the object is now larger than the actual object. For example, enlarge the picture of the person so that the image of their face is much bigger than their real face.

3. Find another photograph of at least two objects at various distances, so that the object closer to the camera appears larger than a bigger object farther away. For example, a car in front of a house may look bigger than the house, even though in reality it is not.

4. Discuss with students how a photograph is a model. In what way is it a model? *(Desired answer: a photograph is a model because it represents another object)*

5. Ask students whether a photograph of an object is the same size as the actual object. *(Desired answer: usually no)* Show students the photograph of an object that is smaller than the real object and the same photograph enlarged on a copier so that it is bigger than the real object. Show students a photograph where an object closer to the camera appears larger than a bigger object farther from the camera. Ask students which model more accurately represents the object(s) in the picture, the first photograph or the last photograph. *(Desired answer: the latter picture is not proportional, and is therefore not as accurate a model)*

6. Tell students that the first photograph is actually a "scale model." Ask students to define this term. *(Desired answer: these are models that are proportional in size to the original)* For example, if you find that the length of your face in a photograph is ten times the diameter of your eye in the photograph, then your actual face should be five times the diameter of your actual eye.

Activity 1: Sun – Ruler of the Solar System

In this activity, students create a pinhole tube and use it to make a model of the Sun. They will then use this model and similar triangles to determine the distance from the schoolyard to the Sun.

Teacher Materials

- Tree Transparency (from back of lesson)
- Sun Transparency (from back of lesson)
- Overhead projector

Student Materials (per student)

- Student Worksheet 1
- Cardboard paper towel tube
- Aluminum foil square (10 cm x 10 cm)
- Graph paper square (10 cm x 10 cm)
- 2 rubber bands
- Thumbtack or pin
- Metric ruler
- Sharp pencil
- Yard stick or meter stick
- Masking tape
- Calculator
- Optional: Markers, stickers, other materials to decorate pinhole tube

Preparation & Procedures

1. Be sure to try this activity ahead of time. It takes some practice. Do not wait for the night before—you will not have the Sun available for practice.

2. You can only do this activity on a sunny day.

3. Cut aluminum foil and graph paper into approximately 10 cm (4 in) squares. Cut enough for each pair of students with extras—aluminum foil tears easily.

4. Make an overhead transparency of the Tree Transparency and Sun Transparency located in the back of the lesson. (You will need to make a transparency of the Moon Transparency in Activity 2, so you may want to make them all at once.)

5. Encourage students to think about how a camera works. You can use the following facilitation to guide students to understand what a camera is actually collecting.

   Tell students that you want to take a picture of a tree. Ask them if the camera is actually collecting the real tree? *(Desired answer: no, it is collecting an image of the tree)* Ask students if you could take a picture of the tree in the dark. *(Desired answer: no)* If this is the case, then what is the camera actually collecting? *(Desired answer: light reflected from the tree)* Ask students if the tree is giving off its own light. *(Desired answer: no, it is reflecting light from the Sun)*

6. Once students realize that cameras are collecting the light reflected from objects, you can use the facilitation below to help them understand how this happens.

   Draw a picture of a simple tree on the blackboard, similar to the tree on the Tree Transparency. Opposite the tree, draw a box and tell students this represents the camera. Ask them what we need if we're going to collect light reflected from the tree. *(Desired answer: a hole in the front of the box)* Draw the hole. Draw a line from the top of the tree through the hole. This represents the light reflected from the top of the tree. Draw another line for the light reflected from the bottom of the tree. (Be sure that students understand that light is being reflected by the tree in all directions, but the camera only collects the light being reflected in the direction of the camera.) Ask students what the image will look like in the back of the camera. *(Desired answer: it will be upside-down because the light from the top of the tree will end up at the bottom of the camera, and vice versa)* Draw an upside-down tree in the back of the camera.

7. The image taken by a camera is actually a scale model of the real image. By using the Tree Transparency and the facilitation below, you can prove this to students by using the properties of similar triangles.

   Cut out the small triangle on the bottom of the Tree Transparency. Display the Tree Transparency using the overhead projector; it should look just like the drawing you created on the board. Ask the students what they notice about the two triangles in the picture. *(Desired answer: they are* *similar)* If the students do not know the answer, it is okay. Similar triangles are triangles that have the same angles, thus making the length of their sides proportional to one another. Show students that the cut-out triangle is identical to the small triangle in the picture, by placing them on top of one another. Flip over the cut-out triangle and place it inside of the big triangle. Move the cut-out triangle around the inside of the big triangle to show the students that the angles are identical to the angles in the big triangle, proving that they are similar. Remind the students of the rules of similar triangles; the angles are the same, and the sides are proportional to one another. Ask the students, if the small triangle is proportional to the big triangle, then what does that make the small triangle? *(Desired answer: a scale model of the big triangle)* Hint: If the students need help, remind them of the *Warm-Up & Pre-Assessment* discussion of scale models. Discuss how this means that the picture of the tree will then be proportionately smaller than the actual tree, making it a scale model.

8. Students will now make a camera of their own. You can use the following facilitation in order for students to design their own camera and experiment.

   Display the materials in the student materials list, and ask students if there is anything they can use to build a camera. *(Desired answer: the paper-towel tube can be used as the box)* Ask students what they can use to make the front of the camera. *(Desired answer: they will need an opaque material for the front of the tube with a small hole in it, like aluminum foil, which will only allow light to enter through the hole)* Ask students what they can use to display the light on the back on the camera. *(Desired answer: paper)* When students select paper for the other end of the tube, ask them how they are going to see the image that would be projected on the inside of the pinhole tube. *(Desired answer: paper is translucent when enough light falls on it)* Then ask students what they should take a picture of to ensure that they will see an image on the other side. *(Desired answer: the Sun should be bright enough to be seen)*

9. Direct students to work in pairs to assemble a pinhole tube. See Part I of Student Worksheet 1 for student procedures.

10. Students can use their pinhole tubes to create a scale model of the Sun. You can use the facilitation below to guide students to this conclusion.

    Display the Sun Transparency; it should remind students of the Tree Transparency. Discuss how, if the triangles were similar in the Tree Transparency, these triangles should also be similar. To prove this, follow the same procedure for the small triangle on the bottom of the Sun Transparency as you did with the Tree Transparency. Once it has been established that the triangles are similar, ask students what the image of the Sun is in comparison to the real Sun. *(Desired answer: it is a scale model of the real Sun)*

11. Students can use the diameter of the Sun as a ruler to measure the distance from the Sun to the Earth. Use the following facilitation and the Sun Transparency to help students develop the procedure.

    Ask students if the model Sun is proportional to the real Sun, then what is proportional to the distance between the Sun and the Earth (front of the pinhole tube). *(Desired answer: the length of the pinhole tube)* Ask students how they could determine the distance from the Sun to the Earth using Sun diameters. Hint: Use the model Sun and the pinhole tube. *(Desired answer: the number of model Suns that will line up along the length of the pinhole tube will be equal to the number of real Suns that will fit between the Sun and the Earth)* Ask students what information they will need and how they will obtain it. *(Desired answer: the only things they need to know in order to determine the distance is the length of the tube, which they can measure, and the size of the model Sun, which they can get by using their pinhole camera to make a model the Sun)*

12. Direct teams to work outside and use the pinhole tube to find the image of the Sun. See Part II of Student Worksheet 1 for student procedures.

    Warn students not to use the pinhole tube as a telescope to look directly at the Sun. NEVER look directly at the Sun; doing so can cause permanent eye damage.

CURRICULUM CONNECTION

Social Studies: Have students research whether Galileo Galilei went blind from staring at the Sun.

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Activity 2: A Model Moon

Lesson Wrap-Up

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Assessment Criteria for Activity 1

5 Points
- All calculations are shown and the results are correct and labeled appropriately.
- Student Worksheet 1 demonstrates an accurate and thorough understanding of scientific concepts underlying the lesson.
- Work is presented in a neat, clear, and organized fashion that is easy to read.

4 Points
- Most calculations are shown and the results are correct and labeled appropriately.
- Student Worksheet 1 demonstrates an accurate and thorough understanding of almost all scientific concepts underlying the lesson.
- Work is presented in a neat, clear, and organized fashion that is usually easy to read.

3 Points
- Some calculations are shown and the results are correct and labeled appropriately.
- Student Worksheet 1 demonstrates an accurate and thorough understanding of most scientific concepts underlying the lesson.
- Work is organized but may be hard to read at times.

2 Points
- Few calculations are shown and the results are correct and labeled.
- Student Worksheet 1 demonstrates an accurate and thorough understanding of some scientific concepts underlying the lesson.
- Work is somewhat organized but hard to read.

1 Point
- Few calculations are shown and the results are accurate and labeled.
- Student Worksheet 1 demonstrates an accurate and thorough understanding of a few scientific concepts underlying the lesson.
- Work is appears sloppy and is hard to read.

0 Points
- No work was completed

Reflection & Discussion

Ask students to report their results: How far away is the Sun, in terms of Sun diameters? Ask the students what else they needed to know in order to express this distance in kilometers. (*Desired answer: the diameter of the Sun*) Ask students to predict how much bigger the Sun is than the Earth. After taking a few suggestions, tell them that its diameter is about 100 times bigger than the Earth's; this means that you could line up 100 Earths across the Sun! Now that they have an idea of the size of the Sun, they can appreciate how far away Earth is from the Sun in Sun diameters. (*Fun Fact: The Sun is so far away that if you were to fly at the speed of a commercial jet plane to the Sun, it would take 17.5 years to get there!*)

Transfer of Knowledge

In order to assess student understanding of similar triangles, allow them to apply what they have learned by having them complete questions 4 and 5 in Student Worksheet 1. (Answers are in *Teacher Answer Key*)

Extensions

- Students may be able to see sunspots on their image of the Sun. Have students research what sunspots are and why they occur. Students should describe how the number of sunspots shows the cyclical nature of the Sun.
- Have students research how the Sun affects the Earth. For example: seasons, climate, night and day, etc. (See *Science Overview* for examples.)
- Have students research how we can harness the Sun's energy to produce power here on Earth.

Placing the Activity Within the Lesson

This activity should help students understand the magnitude of the distance to the Sun. Students should also be aware that they can learn things about the Sun without ever leaving the Earth. Discuss with students whether they can do exactly the same experiment for the Moon. They cannot measure the distance in exactly the same way, since the Moon is not bright enough to give an image through the paper in the back of the pinhole tube. Have them brainstorm how they can use the same concept of a model to measure the distance to the Moon.

Notes on Activity 1:

Activity 2: A Model Moon

In this activity, students will create a Moon-viewer and use it, along with models and the principle of similar triangles (which they learned in Activity 1), to determine the distance to the Moon.

Teacher Materials

- Moon Transparency (from back of lesson)
- Overhead projector

Student Materials (per student)

- Student Worksheet 2
- Index card
- Transparent tape
- 3 meters of string
- Metric ruler
- Scissors

Preparation & Procedures

1. See the Moon Visibility Tables in the back of the lesson for optimal viewing times during the school year.

2. Ask students how big they think the Moon is compared to the Earth. After taking a few suggestions, tell them that it is about one quarter the size of Earth. Ask them how many Moons you would have to line up in order to get the distance between the Earth and the Moon. Take some suggestions, and write their answers on the board for later comparison.

3. Students will use the same principles of models and similar triangles that they used in Activity 1 to calculate the distance to the Moon. Remind the students of the rules of similar triangles: corresponding angles are always the same and corresponding sides are always proportional. Put the Sun Transparency back on the overhead projector, and remind students how they used similar triangles to solve for the distance to the Sun. Ask for suggestions as to how this could be adapted to discover the distance to the Moon. Now put the Moon Transparency on the overhead projector and compare it to their answers. Cut out the small triangle at the bot-

tom of the transparency, and show students how the same principle of similar triangles is used to determine the distance to the Moon.

4. Have students create a Moon-viewer according to the directions in Student Worksheet 2. As a homework assignment, the students will collect and record the appropriate data and complete the required calculations and questions on Student Worksheet 2.

Teaching Tip

If students do not have a Moon-facing window, they may choose to mount the index card on a stick or other temporary device and perform the activity outdoors.

Reflection & Discussion

Ask students how their predictions for the Moon's distance compared to the actual distance. Did anything surprise them? Have students brainstorm situations where knowing how to calculate distances, using this method, might be helpful.

Transfer of Knowledge

Ask students to identify similarities and differences between the method used to determine the distances to the Sun and Moon. Ask students to describe the strengths and weaknesses of both.

Suggestions for answers:
Both methods used the same principle of similar triangles to find the distances. The method used for the Sun would not work for the Moon. The Moon would project an image, but it probably would not be bright enough to be seen through the paper at the back of the pinhole tube. Both methods work for their purposes, but we could not use the method for the Sun with the Moon, and we could not use the method for the Moon with the Sun (it would hurt our eyes).

Curriculum Connection

English: Ask students to write a journal entry exploring their feelings of their place and role in the Solar System.

How Far is Far?
Lesson at a Glance
Science Overview
Conducting the Lesson
Warm Up & Pre-Assessment
Activity 1: Sun – Ruler of the Solar System
Activity 2: A Model Moon
Lesson Wrap-Up
Resources

Assessment Criteria for Activity 2

5 Points

- All calculations are shown and the results are correct and labeled appropriately.
- Student Worksheet 2 demonstrates an accurate and thorough understanding of scientific concepts underlying the lesson.
- Work is presented in a neat, clear, and organized fashion that is easy to read.

4 Points

- Most calculations are shown and the results are correct and labeled appropriately.
- Student Worksheet 2 demonstrates an accurate and thorough understanding of almost all scientific concepts underlying the lesson.
- Work is presented in a neat, clear, and organized fashion that is usually easy to read.

3 Points

- Some calculations are shown and the results are correct and labeled appropriately.
- Student Worksheet 2 demonstrates an accurate and thorough understanding of most scientific concepts underlying the lesson.
- Work is organized but may be hard to read at times.

2 Points

- Few calculations are shown and the results are correct and labeled.
- Student Worksheet 2 demonstrates an accurate and thorough understanding of some scientific concepts underlying the lesson.
- Work is somewhat organized but hard to read.

1 Point

- Few calculations are shown and the results are accurate and labeled.
- Student Worksheet 2 demonstrates an accurate and thorough understanding of a few scientific concepts underlying the lesson.
- Work is appears sloppy and is hard to read.

0 Points

- No work was completed.

Extension

Have students research the orbit of the space shuttle and compare it with that of the Moon. Ask students why they think we have flown humans to near-Earth orbit more often than to the Moon? Have students research the Apollo missions that flew to the Moon, and any difficulties they may have faced along the way. (Fun Fact: If the Earth were the size of a standard globe, then the space shuttle would orbit less than one centimeter from its surface!)

Placing the Activity Within the Lesson

Students have now used the same principles of similar triangles and models to determine the distance to two objects using two different methods. They should understand that these principles, and other uses of models, can be powerful tools for learning.

Notes on Activity 2:

Lesson Wrap-Up

Assessment Criteria for the Lesson

5 Points
- Student used similar triangles to find the answer.
- Student showed work.
- Student's final answer was correct.
- Student explained his or her reasoning.

4 Points
- Student used similar triangles to find the answer.
- Student showed work.
- Student's final answer was flawed.
- Student explained his or her reasoning.

3 Points
- Student used similar triangles to find the answer.
- Student showed most work.
- Student's final answer was flawed.
- Student explained his or her reasoning, but it was not logical.

2 Points
- Student used similar triangles to find the correct answer.
- Student did not show work.
- Student's final answer was flawed.
- Student explained their reasoning, but it was not logical.

1 Point
- Student did not use similar triangles to find the correct answer.
- Student did not show work.
- Student's final answer was flawed.
- Student did not explain their reasoning.

0 Points
- No work completed.

Extensions for the Lesson

Have students research how early astronomers determined the distance to the Sun and Moon. How do their techniques compare to the one used in the lesson?

Transfer of Knowledge for the Lesson

The Moon and the Sun have almost the same apparent size in the sky—this is why total eclipses can occur. If the Sun is 400 times farther away from Earth than the Moon, figure out how much bigger the Sun is than the Moon. (Hint: Use similar triangles!) Explain your answer.

Answer:

Imagine a triangle extending from a camera to both edges of the object you are looking at (like the Sun or Moon). The small angle in the triangles is the object's angular size. If two objects have the same angular size, this means that if we put these triangles inside of one another, we can see that all three angles are the same, which means that the triangles are similar. That means that their sides are proportional to one another, and if one side (distance to Sun) is 400 times longer than its corresponding side (distance to Moon), then another side (diameter of Sun) is 400 times larger than its corresponding side (diameter of Moon). Therefore, the Sun's diameter is 400 times larger than the diameter of the Moon. Students should be able to draw these triangles to aid in their analysis. However, be aware that it would be very difficult to make these drawings to scale, since the distances are so large compared to the objects, see Figure 3 in the Science Overview *for an example.*

Lesson Closure

1. Help students compare the distance from the Earth to the Sun with the distance from the Earth to the Moon. If the Earth is the size of a basketball, then the Moon is four times smaller, about the size of a baseball. The distance between them is 30 Earth diameters, or about the distance across a large room. On this scale, the Sun would be about the size of a house, 100 times bigger than Earth. It would be located 107 houses away, or almost two miles. Discuss how the distance to the Moon is much smaller than the distance to the Sun.

2. Discuss with students the units of their measurements. Were they traditional units, such as meters or feet? *(Desired answer: no, their measurements were made in terms of Sun or Moon diameters)* Discuss with students how anything can be used as a ruler, as long as we define what our ruler is. Ask students what the advantages of this may be. *(Desired answer: one advantage is that it is easier to understand the distances to objects that are very far away if we use rulers that are familiar to us. For example, we could say that a comet can travel 186 miles per second, or we could say that at this speed, you could travel from Washington, D.C., to Los Angeles, CA, in just 15 seconds!)*

Resources

Internet Resources & References

Student-Friendly Web Sites:

Amazing Space – Sun Facts
    amazing-space.stsci.edu/resources/fastfacts/sun.php
How Distant is the Moon?
    www-istp.gsfc.nasa.gov/stargaze/Shipparc.htm

Teacher-Oriented Web Sites:

American Association for the Advancement of Science, Project 2061 Benchmarks for Science Literacy
    www.project2061.org/tools/benchol/bolframe.htm
Determining the Distance to the Moon
    www.stardate.org/resources/ssguide/moon.html
The Earth-Sun Distance
    www.astro-tom.com/getting_started/earth-sun_distance.htm
National Science Education Standards
    www.nap.edu/html/nses/
U.S. Naval Observatory: Moon rise, set and altitude data
    aa.usno.navy.mil/data/
Voyage Online
    www.voyageonline.org

Acknowledgments

Activity 1 has been adapted from Activity 6.3, Building and Using a Pinhole Tube found in Project STAR The Universe in Your Hands, Kendall/Hunt Publishing Company, 1993, ISBN 0-8403-7715-0. Copyright 1993 by the President and Fellows of Harvard College.

NOTES:

Moon Visibility Table
Fall / Winter 2005

The following table shows the dates and times when the Moon will be optimally visible in Washington, D.C., to perform Activity 2. The times for optimal visibility in the continental USA are similar (though they vary somewhat).

You can find the altitude of the Moon, as well as moonrise and moonset times for your exact location, at the U.S. Naval Observatory Astronomical Applications Department's Data Services web site: http://aa.usno.navy.mil/data/

The table show the date, rise time, and set time of the Moon when it is at least half full (no crescents), to make sure the Moon fills enough of the Moon-viewer cut-out to make the measurement accurate. Note that in most cases, the rise time is after the set time. This is because the Moon (when it is at least half full) is usually visible at midnight, and then it will set during the day, but rise again at night.

Date	Moon Rise	Moon Set
Mon, Sep 12	3:00 p.m.	11:55 p.m.
Tue, Sep 13	3:54 p.m.	
Wed, Sep 14	4:39 p.m.	1:09 a.m.
Thu, Sep 15	5:16 p.m.	2:28 a.m.
Fri, Sep 16	5:47 p.m.	3:48 a.m.
Sat, Sep 17	6:14 p.m.	5:05 a.m.
Sun, Sep 18	6:40 p.m.	6:21 a.m.
Mon, Sep 19	7:05 p.m.	7:34 a.m.
Tue, Sep 20	7:33 p.m.	8:47 a.m.
Wed, Sep 21	8:04 p.m.	9:59 a.m.
Thu, Sep 22	8:39 p.m.	11:10 a.m.
Fri, Sep 23	9:22 p.m.	12:17 p.m.
Sat, Sep 24	10:11 p.m.	1:18 p.m.
Sun, Sep 25	11:06 p.m.	2:11 p.m.
Tue, Oct 11	2:36 p.m.	
Wed, Oct 12	3:14 p.m.	12:10 a.m.
Thu, Oct 13	3:46 p.m.	1:27 a.m.
Fri, Oct 14	4:13 p.m.	2:43 a.m.
Sat, Oct 15	4:39 p.m.	3:57 a.m.
Sun, Oct 16	5:04 p.m.	5:10 a.m.
Mon, Oct 17	5:30 p.m.	6:22 a.m.
Tue, Oct 18	6:00 p.m.	7:35 a.m.
Wed, Oct 19	6:33 p.m.	8:48 a.m.
Thu, Oct 20	7:13 p.m.	9:58 a.m.
Fri, Oct 21	8:01 p.m.	11:04 a.m.
Sat, Oct 22	8:54 p.m.	12:02 p.m.
Sun, Oct 23	9:53 p.m.	12:51 p.m.
Mon, Oct 24	10:55 p.m.	1:31 p.m.
Wed, Nov 9	1:48 p.m.	
Thu, Nov 10	2:16 p.m.	12:29 a.m.
Fri, Nov 11	2:41 p.m.	1:42 a.m.
Sat, Nov 12	3:06 p.m.	2:53 a.m.
Sun, Nov 13	3:31 p.m.	4:03 a.m.
Mon, Nov 14	3:58 p.m.	5:14 a.m.
Tue, Nov 15	4:29 p.m.	6:26 a.m.
Wed, Nov 16	5:06 p.m.	7:37 a.m.
Thu, Nov 17	5:50 p.m.	8:46 a.m.
Fri, Nov 18	6:42 p.m.	9:48 a.m.
Sat, Nov 19	7:40 p.m.	10:42 a.m.

Sun, Nov 20	8:41 p.m.	11:26 a.m.
Mon, Nov 21	9:44 p.m.	12:03 p.m.
Tue, Nov 22	10:46 p.m.	12:33 p.m.
Wed, Nov 23	11:46 p.m.	12:58 p.m.
Fri, Dec 9	1:10 p.m.	12:44 a.m.
Sat, Dec 10	1:34 p.m.	1:53 a.m.
Sun, Dec 11	2:00 p.m.	3:02 a.m.
Mon, Dec 12	2:29 p.m.	4:12 a.m.
Tues, Dec 13	3:03 p.m.	5:22 a.m.
Wed, Dec 14	3:44 p.m.	6:30 a.m.
Thu, Dec 15	4:32 p.m.	7:35 a.m.
Fri, Dec 16	5:28 p.m.	8:32 a.m.
Sat, Dec 17	6:28 p.m.	9:20 a.m.
Sun, Dec 18	7:31 p.m.	10:00 a.m.
Mon, Dec 19	8:33 p.m.	10:32 a.m.
Tue, Dec 20	9:34 p.m.	10:59 a.m.
Wed, Dec 21	10:34 p.m.	11:22 a.m.
Thu, Dec 22	11:33 p.m.	11:44 a.m.
Fri, Dec 23		12:04 p.m.

Teaching Tip

Do not plan the activity for the last possible date shown in the table. If you do, it might be too cloudy to see the Moon, and there might not be any rain dates available.

Moon Visibility Table
2006

The following table shows the dates and times when the Moon will be optimally visible in Washington, D.C., to perform Activity 2. The times for optimal visibility in the continental USA are similar (though they vary somewhat).

You can find the altitude of the Moon, as well as moonrise and moonset times for your exact location, at the U.S. Naval Observatory Astronomical Applications Department's Data Services web site: http://aa.usno.navy.mil/data/

The table show the date, rise time, and set time of the Moon when it is at least half full (no crescents), to make sure the Moon fills enough of the Moon-viewer cut-out to make the measurement accurate. Note that in most cases, the rise time is after the set time. This is because the Moon (when it is at least half full) is usually visible at midnight, and then it will set during the day, but rise again at night.

Date	Moon Rise	Moon Set
Sat, Jan 7	12:03 p.m.	12:55 a.m.
Sun, Jan 8	12:31 p.m.	2:04 a.m.
Mon, Jan 9	1:03 p.m.	3:13 a.m.
Tue, Jan 10	1:41 p.m.	4:21 a.m.
Wed, Jan 11	2:26 p.m.	5:26 a.m.
Thu, Jan 12	3:19 p.m.	6:25 a.m.
Fri, Jan 13	4:18 p.m.	7:16 a.m.
Sat, Jan 14	5:20 p.m.	7:58 a.m.
Sun, Jan 15	6:23 p.m.	8:33 a.m.
Mon, Jan 16	7:24 p.m.	9:01 a.m.
Tue, Jan 17	8:24 p.m.	9:25 a.m.
Wed, Jan 18	9:23 p.m.	9:47 a.m.
Thu, Jan 19	10:22 p.m.	10:07 a.m.
Fri, Jan 20	11:21 p.m.	10:27 a.m.
Sat, Jan 21	12:00 a.m.	10:48 a.m.
Sun, Jan 22	12:22 a.m.	11:11 a.m.
Mon, Feb 6	11:40 a.m.	2:14 a.m.
Tue, Feb 7	12:23 p.m.	3:20 a.m.
Wed, Feb 8	1:14 p.m.	4:21 a.m.
Thu, Feb 9	2:11 p.m.	5:14 a.m.
Fri, Feb 10	3:12 p.m.	5:58 a.m.
Sat, Feb 11	4:14 p.m.	6:34 a.m.
Sun, Feb 12	5:16 p.m.	7:04 a.m.
Mon, Feb 13	6:17 p.m.	7:30 a.m.
Tue, Feb 14	7:16 p.m.	7:52 a.m.
Wed, Feb 15	8:15 p.m.	8:12 a.m.
Thu, Feb 16	9:13 p.m.	8:32 a.m.
Fri, Feb 17	10:13 p.m.	8:52 a.m.
Sat, Feb 18	11:16 p.m.	9:14 a.m.
Sun, Feb 19	12:00 a.m.	9:39 a.m.
Mon, Feb 20	12:21 a.m.	10:09 a.m.
Tue, Feb 21	1:29 a.m.	10:47 a.m.
Tue, Mar 7	11:08 a.m.	2:15 a.m.
Wed, Mar 8	12:04 p.m.	3:11 a.m.
Thu, Mar 9	1:04 p.m.	3:58 a.m.
Fri, Mar 10	2:06 p.m.	4:36 a.m.
Sat, Mar 11	3:08 p.m.	5:08 a.m.
Sun, Mar 12	4:09 p.m.	5:34 a.m.
Mon, Mar 13	5:09 p.m.	5:57 a.m.

Tue, Mar 14	6:08 p.m.	6:18 a.m.
Wed, Mar 15	7:07 p.m.	6:38 a.m.
Thu, Mar 16	8:07 p.m.	6:58 a.m.
Fri, Mar 17	9:08 p.m.	7:19 a.m.
Sat, Mar 18	10:13 p.m.	7:43 a.m.
Sun, Mar 19	11:19 p.m.	8:11 a.m.
Mon, Mar 20	12:00 a.m.	8:45 a.m.
Tue, Mar 21	12:27 a.m.	9:28 a.m.
Wed, Mar 22	1:32 a.m.	10:22 a.m.
Thu, Apr 6	11:56 a.m.	2:36 a.m.
Fri, Apr 7	12:59 p.m.	3:10 a.m.
Sat, Apr 8	2:01 p.m.	3:38 a.m.
Sun, Apr 9	3:01 p.m.	4:02 a.m.
Mon, Apr 10	4:00 p.m.	4:24 a.m.
Tue, Apr 11	4:59 p.m.	4:44 a.m.
Wed, Apr 12	5:59 p.m.	5:04 a.m.
Thu, Apr 13	7:00 p.m.	5:24 a.m.
Fri, Apr 14	8:04 p.m.	5:48 a.m.
Sat, Apr 15	9:11 p.m.	6:14 a.m.

Sun, Apr 16	10:19 p.m.	6:47 a.m.
Mon, Apr 17	11:25 p.m.	7:27 a.m.
Tue, Apr 18	12:00 a.m.	8:17 a.m.
Wed, Apr 19	12:25 a.m.	9:18 a.m.
Thu, Apr 20	1:18 a.m.	10:27 a.m.
Fri, May 5	11:50 a.m.	1:40 a.m.
Sat, May 6	12:51 p.m.	2:05 a.m.
Sun, May 7	1:50 p.m.	2:28 a.m.
Mon, May 8	2:49 p.m.	2:48 a.m.
Tue, May 9	3:48 p.m.	3:08 a.m.
Wed, May 10	4:49 p.m.	3:28 a.m.
Thu, May 11	5:52 p.m.	3:51 a.m.
Fri, May 12	6:59 p.m.	4:16 a.m.
Sat, May 13	8:07 p.m.	4:47 a.m.
Sun, May 14	9:15 p.m.	5:25 a.m.
Mon, May 15	10:19 p.m.	6:13 a.m.
Tue, May 16	11:15 p.m.	7:11 a.m.
Wed, May 17	12:00 a.m.	8:18 a.m.
Thu, May 18	12:01 a.m.	9:31 a.m.

TEACHING TIP

Do not plan the activity for the last possible date shown in the table. If you do, it might be too cloudy to see the Moon, and there might not be any rain dates available.

Wed, Jun 7	3:38 p.m.	1:53 a.m.
Thu, Jun 8	4:43 p.m.	2:17 a.m.
Fri, Jun 9	5:51 p.m.	2:45 a.m.
Sat, Jun 10	7:00 p.m.	3:20 a.m.
Sun, Jun 11	8:07 p.m.	4:05 a.m.
Mon, Jun 12	9:07 p.m.	5:00 a.m.
Tue, Jun 13	9:58 p.m.	6:06 a.m.
Wed, Jun 14	10:40 p.m.	7:20 a.m.
Thu, Jun 15	11:13 p.m.	8:36 a.m.
Fri, Jun 16	11:42 p.m.	9:51 a.m.
Sat, Jun 17	12:00 a.m.	11:04 a.m.
Sun, Jun 18	12:08 a.m.	12:15 p.m.
Tue, Jul 4	1:24 p.m.	12:00 a.m.
Wed, Jul 5	2:27 p.m.	12:17 a.m.
Thu, Jul 6	3:33 p.m.	12:43 a.m.
Fri, Jul 7	4:41 p.m.	1:15 a.m.
Sat, Jul 8	5:49 p.m.	1:55 a.m.
Sun, Jul 9	6:53 p.m.	2:45 a.m.
Mon, Jul 10	7:49 p.m.	3:48 a.m.
Tue, Jul 11	8:35 p.m.	5:00 a.m.
Wed, Jul 12	9:13 p.m.	6:17 a.m.
Thu, Jul 13	9:44 p.m.	7:35 a.m.
Fri, Jul 14	10:11 p.m.	8:52 a.m.
Sat, Jul 15	10:36 p.m.	10:05 a.m.
Sun, Jul 16	11:01 p.m.	11:17 a.m.
Mon, Jul 17	11:28 p.m.	12:29 p.m.
Thu, Aug 3	2:23 p.m.	11:46 p.m.
Fri, Aug 4	3:30 p.m.	12:00 a.m.
Sat, Aug 5	4:36 p.m.	12:31 a.m.

Sun, Aug 6	5:35 p.m.	1:27 a.m.
Mon, Aug 7	6:26 p.m.	2:35 a.m.
Tue, Aug 8	7:07 p.m.	3:51 a.m.
Wed, Aug 9	7:42 p.m.	5:10 a.m.
Thu, Aug 10	8:11 p.m.	6:29 a.m.
Fri, Aug 11	8:38 p.m.	7:47 a.m.
Sat, Aug 12	9:03 p.m.	9:02 a.m.
Sun, Aug 13	9:30 p.m.	10:16 a.m.
Mon, Aug 14	9:59 p.m.	11:30 a.m.
Tue, Aug 15	10:33 p.m.	12:44 p.m.
Fri, Sep 1	2:20 p.m.	11:12 p.m.
Sat, Sep 2	3:21 p.m.	12:00 a.m.
Sun, Sep 3	4:14 p.m.	12:13 a.m.
Mon, Sep 4	4:59 p.m.	1:24 a.m.
Tue, Sep 5	5:36 p.m.	2:41 a.m.
Wed, Sep 6	6:08 p.m.	4:00 a.m.
Thu, Sep 7	6:36 p.m.	5:19 a.m.
Fri, Sep 8	7:02 p.m.	6:36 a.m.
Sat, Sep 9	7:29 p.m.	7:53 a.m.
Sun, Sep 10	7:58 p.m.	9:10 a.m.
Mon, Sep 11	8:31 p.m.	10:27 a.m.
Tue, Sep 12	9:10 p.m.	11:42 a.m.
Wed, Sep 13	9:56 p.m.	12:54 p.m.
Thu, Sep 14	10:50 p.m.	1:58 p.m.
Sun, Oct 1	2:52 p.m.	12:00 a.m.
Mon, Oct 2	3:31 p.m.	12:17 a.m.
Tue, Oct 3	4:04 p.m.	1:33 a.m.
Wed, Oct 4	4:33 p.m.	2:50 a.m.
Thu, Oct 5	5:00 p.m.	4:07 a.m.

Fri, Oct 6	5:27 p.m.	5:24 a.m.
Sat, Oct 7	5:55 p.m.	6:41 a.m.
Sun, Oct 8	6:26 p.m.	8:00 a.m.
Mon, Oct 9	7:03 p.m.	9:18 a.m.
Tue, Oct 10	7:48 p.m.	10:35 a.m.
Wed, Oct 11	8:41 p.m.	11:45 a.m.
Thu, Oct 12	9:41 p.m.	12:45 p.m.
Fri, Oct 13	10:45 p.m.	1:35 p.m.
Mon, Oct 30	2:03 p.m.	12:00 a.m.
Tue, Oct 31	2:32 p.m.	12:30 a.m.
Wed, Nov 1	2:59 p.m.	1:44 a.m.
Thu, Nov 2	3:25 p.m.	2:58 a.m.
Fri, Nov 3	3:51 p.m.	4:13 a.m.
Sat, Nov 4	4:21 p.m.	5:30 a.m.
Sun, Nov 5	4:55 p.m.	6:48 a.m.
Mon, Nov 6	5:36 p.m.	8:07 a.m.
Tue, Nov 7	6:26 p.m.	9:22 a.m.
Wed, Nov 8	7:25 p.m.	10:29 a.m.
Thu, Nov 9	8:30 p.m.	11:25 a.m.
Fri, Nov 10	9:36 p.m.	12:10 p.m.
Sat, Nov 11	10:42 p.m.	12:45 p.m.
Sun, Nov 12	11:45 p.m.	1:14 p.m.
Wed, Nov 29	1:26 p.m.	12:43 a.m.
Thu, Nov 30	1:51 p.m.	1:55 a.m.
Fri, Dec 1	2:18 p.m.	3:08 a.m.
Sat, Dec 2	2:49 p.m.	4:23 a.m.
Sun, Dec 3	3:26 p.m.	5:40 a.m.
Mon, Dec 4	4:12 p.m.	6:57 a.m.
Tue, Dec 5	5:07 p.m.	8:08 a.m.

Wed, Dec 6	6:10 p.m.	9:10 a.m.
Thu, Dec 7	7:17 p.m.	10:01 a.m.
Fri, Dec 8	8:25 p.m.	10:41 a.m.
Sat, Dec 9	9:31 p.m.	11:13 a.m.
Sun, Dec 10	10:33 p.m.	11:39 a.m.
Mon, Dec 11	11:33 p.m.	12:02 p.m.
Tue, Dec 12	12:00 a.m.	12:23 p.m.
Thu, Dec 28	12:20 p.m.	12:57 a.m.
Fri, Dec 29	12:49 p.m.	2:09 a.m.
Sat, Dec 30	1:22 p.m.	3:23 a.m.
Sun, Dec 31	2:03 p.m.	4:38 a.m.

Moon Visibility Table
2007

The following table shows the dates and times when the Moon will be optimally visible in Washington, D.C., to perform Activity 2. The times for optimal visibility in the continental USA are similar (though they vary somewhat).

You can find the altitude of the Moon, as well as moonrise and moonset times for your exact location, at the U.S. Naval Observatory Astronomical Applications Department's Data Services web site: http://aa.usno.navy.mil/data/

The table show the date, rise time, and set time of the Moon when it is at least half full (no crescents), to make sure the Moon fills enough of the Moon-viewer cut-out to make the measurement accurate. Note that in most cases, the rise time is after the set time. This is because the Moon (when it is at least half full) is usually visible at midnight, and then it will set during the day, but rise again at night.

Date	Moon Rise	Moon Set
Mon, Jan 1	2:53 p.m.	5:50 a.m.
Tue, Jan 2	3:52 p.m.	6:55 a.m.
Wed, Jan 3	4:58 p.m.	7:50 a.m.
Thu, Jan 4	6:06 p.m.	8:35 a.m.
Fri, Jan 5	7:14 p.m.	9:10 a.m.
Sat, Jan 6	8:18 p.m.	9:39 a.m.
Sun, Jan 7	9:20 p.m.	10:03 a.m.
Mon, Jan 8	10:19 p.m.	10:25 a.m.
Tue, Jan 9	11:18 p.m.	10:45 a.m.
Wed, Jan 10	12:00 a.m.	11:05 a.m.
Thu, Jan 11	12:16 a.m.	11:26 a.m.
Fri, Jan 26	11:23 a.m.	1:14 a.m.
Sat, Jan 27	12:01 p.m.	2:28 a.m.
Sun, Jan 28	12:47 p.m.	3:40 a.m.
Mon, Jan 29	1:42 p.m.	4:46 a.m.
Tue, Jan 30	2:44 p.m.	5:43 a.m.
Wed, Jan 31	3:51 p.m.	6:31 a.m.
Thu, Feb 1	4:58 p.m.	7:09 a.m.
Fri, Feb 2	6:04 p.m.	7:40 a.m.
Sat, Feb 3	7:07 p.m.	8:05 a.m.
Sun, Feb 4	8:08 p.m.	8:28 a.m.
Mon, Feb 5	9:07 p.m.	8:48 a.m.
Tue, Feb 6	10:05 p.m.	9:08 a.m.
Wed, Feb 7	11:04 p.m.	9:29 a.m.
Thu, Feb 8	12:00 a.m.	9:51 a.m.
Fri, Feb 9	12:05 a.m.	10:16 a.m.
Sat, Feb 10	1:08 a.m.	10:46 a.m.
Sun, Feb 25	11:36 a.m.	2:40 a.m.
Mon, Feb 26	12:36 p.m.	3:40 a.m.
Tue, Feb 27	1:41 p.m.	4:30 a.m.
Wed, Feb 28	2:48 p.m.	5:10 a.m.
Thu, Mar 1	3:53 p.m.	5:42 a.m.
Fri, Mar 2	4:57 p.m.	6:09 a.m.
Sat, Mar 3	5:58 p.m.	6:32 a.m.
Sun, Mar 4	6:57 p.m.	6:53 a.m.
Mon, Mar 5	7:56 p.m.	7:13 a.m.
Tue, Mar 6	8:55 p.m.	7:33 a.m.
Wed, Mar 7	9:55 p.m.	7:55 a.m.
Thu, Mar 8	10:56 p.m.	8:18 a.m.

Fri, Mar 9	11:59 p.m.	8:46 a.m.
Sat, Mar 10	12:00 a.m.	9:20 a.m.
Sun, Mar 11	1:02 a.m.	10:01 a.m.
Mon, Mar 12	2:02 a.m.	10:52 a.m.
Mon, Mar 26	11:33 a.m.	2:28 a.m.
Tue, Mar 27	12:40 p.m.	3:11 a.m.
Wed, Mar 28	1:46 p.m.	3:45 a.m.
Thu, Mar 29	2:49 p.m.	4:14 a.m.
Fri, Mar 30	3:50 p.m.	4:38 a.m.
Sat, Mar 31	4:50 p.m.	4:59 a.m.
Sun, Apr 1	5:48 p.m.	5:19 a.m.
Mon, Apr 2	6:47 p.m.	5:39 a.m.
Tue, Apr 3	7:47 p.m.	6:00 a.m.
Wed, Apr 4	8:48 p.m.	6:23 a.m.
Thu, Apr 5	9:50 p.m.	6:49 a.m.
Fri, Apr 6	10:53 p.m.	7:21 a.m.
Sat, Apr 7	11:53 p.m.	7:59 a.m.
Sun, Apr 8	12:00 a.m.	8:46 a.m.
Mon, Apr 9	12:49 a.m.	9:41 a.m.

Tue, Apr 10	1:39 a.m.	10:45 a.m.
Wed, Apr 25	12:42 p.m.	2:17 a.m.
Thu, Apr 26	1:44 p.m.	2:42 a.m.
Fri, Apr 27	2:44 p.m.	3:04 a.m.
Sat, Apr 28	3:42 p.m.	3:25 a.m.
Sun, Apr 29	4:40 p.m.	3:45 a.m.
Mon, Apr 30	5:40 p.m.	4:05 a.m.
Tue, May 1	6:40 p.m.	4:27 a.m.
Wed, May 2	7:42 p.m.	4:53 a.m.
Thu, May 3	8:45 p.m.	5:23 a.m.
Fri, May 4	9:47 p.m.	5:59 a.m.
Sat, May 5	10:44 p.m.	6:43 a.m.
Sun, May 6	11:35 p.m.	7:36 a.m.
Mon, May 7	12:00 a.m.	8:37 a.m.
Tue, May 8	12:19 a.m.	9:44 a.m.
Wed, May 9	12:56 a.m.	10:53 a.m.
Thu, May 10	1:27 a.m.	12:04 p.m.
Thu, May 24	12:35 p.m.	1:08 a.m.
Fri, May 25	1:35 p.m.	1:29 a.m.

TEACHING TIP

Do not plan the activity for the last possible date shown in the table. If you do, it might be too cloudy to see the Moon, and there might not be any rain dates .available.

Sat, May 26	2:33 p.m.	1:49 a.m.
Sun, May 27	3:32 p.m.	2:10 a.m.
Mon, May 28	4:32 p.m.	2:31 a.m.
Tue, May 29	5:33 p.m.	2:56 a.m.
Wed, May 30	6:36 p.m.	3:24 a.m.
Thu, May 31	7:39 p.m.	3:59 a.m.
Fri, Jun 1	8:38 p.m.	4:41 a.m.
Sat, Jun 2	9:32 p.m.	5:32 a.m.
Sun, Jun 3	10:18 p.m.	6:31 a.m.
Fri, Jun 16	11:42 p.m.	9:51 a.m.
Mon, Jun 4	10:57 p.m.	7:37 a.m.
Tue, Jun 5	11:30 p.m.	8:45 a.m.
Wed, Jun 6	11:58 p.m.	9:55 a.m.
Thu, Jun 7	12:00 a.m.	11:05 a.m.
Fri, Jun 8	12:24 a.m.	12:15 p.m.
Sat, Jun 23	1:22 p.m.	12:13 a.m.
Sun, Jun 24	2:22 p.m.	12:34 a.m.
Mon, Jun 25	3:23 p.m.	12:58 a.m.
Tue, Jun 26	4:25 p.m.	1:24 a.m.
Wed, Jun 27	5:28 p.m.	1:57 a.m.
Thu, Jun 28	6:29 p.m.	2:36 a.m.
Fri, Jun 29	7:26 p.m.	3:24 a.m.
Sat, Jun 30	8:15 p.m.	4:22 a.m.
Sun, Jul 1	8:57 p.m.	5:26 a.m.
Mon, Jul 2	9:32 p.m.	6:36 a.m.
Tue, Jul 3	10:01 p.m.	7:47 a.m.
Wed, Jul 4	10:28 p.m.	8:57 a.m.
Thu, Jul 5	10:52 p.m.	10:07 a.m.
Fri, Jul 6	11:17 p.m.	11:17 a.m.
Sat, Jul 7	11:43 p.m.	12:28 p.m.

Sun, Jul 22	1:10 p.m.	11:24 p.m.
Mon, Jul 23	2:12 p.m.	11:54 p.m.
Tue, Jul 24	3:15 p.m.	12:00 a.m.
Wed, Jul 25	4:17 p.m.	12:30 a.m.
Thu, Jul 26	5:15 p.m.	1:15 a.m.
Fri, Jul 27	6:08 p.m.	2:08 a.m.
Sat, Jul 28	6:53 p.m.	3:11 a.m.
Sun, Jul 29	7:31 p.m.	4:20 a.m.
Mon, Jul 30	8:03 p.m.	5:32 a.m.
Tue, Jul 31	8:31 p.m.	6:44 a.m.
Wed, Aug 1	8:56 p.m.	7:56 a.m.
Thu, Aug 2	9:21 p.m.	9:07 a.m.
Fri, Aug 3	9:47 p.m.	10:19 a.m.
Sat, Aug 4	10:16 p.m.	11:32 a.m.
Sun, Aug 5	10:49 p.m.	12:46 p.m.
Tue, Aug 21	2:03 p.m.	11:06 p.m.
Wed, Aug 22	3:03 p.m.	11:55 p.m.
Thu, Aug 23	3:58 p.m.	12:00 a.m.
Fri, Aug 24	4:45 p.m.	12:53 a.m.
Sat, Aug 25	5:26 p.m.	1:59 a.m.
Sun, Aug 26	6:01 p.m.	3:10 a.m.
Mon, Aug 27	6:31 p.m.	4:23 a.m.
Tue, Aug 28	6:58 p.m.	5:36 a.m.
Wed, Aug 29	7:23 p.m.	6:50 a.m.
Thu, Aug 30	7:50 p.m.	8:03 a.m.
Fri, Aug 31	8:18 p.m.	9:18 a.m.
Sat, Sep 1	8:50 p.m.	10:34 a.m.
Sun, Sep 2	9:29 p.m.	11:51 a.m.
Mon, Sep 3	10:16 p.m.	1:06 p.m.
Thu, Sep 20	2:37 p.m.	11:40 p.m.

Fri, Sep 21	3:20 p.m.	12:00 a.m.
Sat, Sep 22	3:56 p.m.	12:48 a.m.
Sun, Sep 23	4:28 p.m.	1:59 a.m.
Mon, Sep 24	4:56 p.m.	3:11 a.m.
Tue, Sep 25	5:22 p.m.	4:25 a.m.
Wed, Sep 26	5:49 p.m.	5:39 a.m.
Thu, Sep 27	6:17 p.m.	6:55 a.m.
Fri, Sep 28	6:48 p.m.	8:13 a.m.
Sat, Sep 29	7:26 p.m.	9:32 a.m.
Sun, Sep 30	8:11 p.m.	10:51 a.m.
Mon, Oct 1	9:06 p.m.	12:04 p.m.
Tue, Oct 2	10:09 p.m.	1:08 p.m.
Wed, Oct 3	11:17 p.m.	2:01 p.m.
Sat, Oct 20	2:25 p.m.	12:00 a.m.
Sun, Oct 21	2:54 p.m.	12:49 a.m.
Mon, Oct 22	3:20 p.m.	2:00 a.m.
Tue, Oct 23	3:46 p.m.	3:12 a.m.
Tue, Oct 23	3:46 p.m.	3:12 a.m.
Wed, Oct 24	4:13 p.m.	4:26 a.m.
Thu, Oct 25	4:43 p.m.	5:43 a.m.
Fri, Oct 26	5:18 p.m.	7:03 a.m.
Sat, Oct 27	6:01 p.m.	8:24 a.m.
Sun, Oct 28	6:53 p.m.	9:43 a.m.
Mon, Oct 29	7:56 p.m.	10:54 a.m.
Tue, Oct 30	9:05 p.m.	11:54 a.m.
Wed, Oct 31	10:15 p.m.	12:41 p.m.
Thu, Nov 1	11:25 p.m.	1:18 p.m.
Sun, Nov 18	1:20 p.m.	12:00 a.m.
Mon, Nov 19	1:45 p.m.	12:52 a.m.
Tue, Nov 20	2:10 p.m.	2:02 a.m.

Wed, Nov 21	2:38 p.m.	3:14 a.m.
Thu, Nov 22	3:09 p.m.	4:31 a.m.
Fri, Nov 23	3:48 p.m.	5:51 a.m.
Sat, Nov 24	4:36 p.m.	7:12 a.m.
Sun, Nov 25	5:35 p.m.	8:29 a.m.
Mon, Nov 26	6:43 p.m.	9:37 a.m.
Tue, Nov 27	7:57 p.m.	10:31 a.m.
Wed, Nov 28	9:09 p.m.	11:14 a.m.
Thu, Nov 29	10:19 p.m.	11:47 a.m.
Fri, Nov 30	11:24 p.m.	12:15 p.m.
Sat, Dec 1	12:00 a.m.	12:38 p.m.
Tue, Dec 18	12:37 p.m.	12:57 a.m.
Wed, Dec 19	1:05 p.m.	2:09 a.m.
Thu, Dec 20	1:39 p.m.	3:25 a.m.
Fri, Dec 21	2:21 p.m.	4:43 a.m.
Sat, Dec 22	3:14 p.m.	6:01 a.m.
Sun, Dec 23	4:17 p.m.	7:13 a.m.
Mon, Dec 24	5:30 p.m.	8:15 a.m.
Tue, Dec 25	6:45 p.m.	9:04 a.m.
Wed, Dec 26	7:58 p.m.	9:42 a.m.
Thu, Dec 27	9:08 p.m.	10:13 a.m.
Fri, Dec 28	10:13 p.m.	10:39 a.m.
Sat, Dec 29	11:15 p.m.	11:02 a.m.
Sun, Dec 30	12:00 a.m.	11:23 a.m.
Mon, Dec 31	12:15 a.m.	11:45 a.m.

Moon Visibility Table
2008

The following table shows the dates and times when the Moon will be optimally visible in Washington, D.C., to perform Activity 2. The times for optimal visibility in the continental USA are similar (though they vary somewhat).

You can find the altitude of the Moon, as well as moonrise and moonset times for your exact location, at the U.S. Naval Observatory Astronomical Applications Department's Data Services web site: http://aa.usno.navy.mil/data/

The table show the date, rise time, and set time of the Moon when it is at least half full (no crescents), to make sure the Moon fills enough of the Moon-viewer cut-out to make the measurement accurate. Note that in most cases, the rise time is after the set time. This is because the Moon (when it is at least half full) is usually visible at midnight, and then it will set during the day, but rise again at night.

Date	Moon Rise	Moon Set
Wed, Jan 16	11:37 a.m.	1:11 a.m.
Thu, Jan 17	12:14 p.m.	2:25 a.m.
Fri, Jan 18	1:01 p.m.	3:41 a.m.
Sat, Jan 19	1:58 p.m.	4:54 a.m.
Sun, Jan 20	3:05 p.m.	5:59 a.m.
Mon, Jan 21	4:18 p.m.	6:52 a.m.
Tue, Jan 22	5:33 p.m.	7:35 a.m.
Wed, Jan 23	6:45 p.m.	8:10 a.m.
Thu, Jan 24	7:54 p.m.	8:38 a.m.
Fri, Jan 25	8:59 p.m.	9:03 a.m.
Sat, Jan 26	10:01 p.m.	9:25 a.m.
Sun, Jan 27	11:02 p.m.	9:47 a.m.
Mon, Jan 28	12:00 a.m.	10:09 a.m.
Tue, Jan 29	12:03 a.m.	10:34 a.m.
Wed, Jan 30	1:04 a.m.	11:01 a.m.
Thu, Feb 14	10:57 a.m.	1:31 a.m.
Fri, Feb 15	11:49 a.m.	2:43 a.m.
Sat, Feb 16	12:51 p.m.	3:49 a.m.
Sun, Feb 17	2:00 p.m.	4:45 a.m.
Mon, Feb 18	3:13 p.m.	5:31 a.m.
Tue, Feb 19	4:25 p.m.	6:08 a.m.
Wed, Feb 20	5:35 p.m.	6:38 a.m.
Thu, Feb 21	6:41 p.m.	7:04 a.m.
Fri, Feb 22	7:45 p.m.	7:27 a.m.
Sat, Feb 23	8:47 p.m.	7:49 a.m.
Sun, Feb 24	9:49 p.m.	8:11 a.m.
Mon, Feb 25	10:51 p.m.	8:35 a.m.
Tue, Feb 26	11:52 p.m.	9:01 a.m.
Wed, Feb 27	12:00 a.m.	9:32 a.m.
Thu, Feb 28	12:54 a.m.	10:08 a.m.
Sat, Mar 15	11:51 a.m.	2:42 a.m.
Sun, Mar 16	1:02 p.m.	3:30 a.m.
Mon, Mar 17	2:13 p.m.	4:08 a.m.
Tue, Mar 18	3:22 p.m.	4:40 a.m.
Wed, Mar 19	4:28 p.m.	5:06 a.m.
Thu, Mar 20	5:31 p.m.	5:30 a.m.
Fri, Mar 21	6:34 p.m.	5:52 a.m.
Sat, Mar 22	7:36 p.m.	6:14 a.m.
Sun, Mar 23	8:37 p.m.	6:37 a.m.

How Far is Far?

Lesson at a Glance

Science Overview

Conducting the Lesson

Resources

Internet Resources & References

Moon Visibility Tables

Teacher Answer Key

Mon, Mar 24	9:39 p.m.	7:03 a.m.
Tue, Mar 25	10:41 p.m.	7:32 a.m.
Wed, Mar 26	11:41 p.m.	8:06 a.m.
Thu, Mar 27	12:00 a.m.	8:46 a.m.
Fri, Mar 28	12:38 a.m.	9:34 a.m.
Tue, Mar 27	12:40 p.m.	3:11 a.m.
Mon, Mar 24	9:39 p.m.	7:03 a.m.
Tue, Mar 25	10:41 p.m.	7:32 a.m.
Wed, Mar 26	11:41 p.m.	8:06 a.m.
Thu, Mar 27	12:00 a.m.	8:46 a.m.
Fri, Mar 28	12:38 a.m.	9:34 a.m.
Thu, Apr 17	4:25 p.m.	3:57 a.m.
Fri, Apr 18	5:26 p.m.	4:19 a.m.
Sat, Apr 19	6:27 p.m.	4:42 a.m.
Sun, Apr 20	7:29 p.m.	5:06 a.m.
Mon, Apr 21	8:31 p.m.	5:34 a.m.
Tue, Apr 22	9:32 p.m.	6:06 a.m.
Wed, Apr 23	10:29 p.m.	6:44 a.m.
Thu, Apr 24	11:22 p.m.	7:29 a.m.

Fri, Apr 25	12:00 a.m.	8:21 a.m.
Sat, Apr 26	12:09 a.m.	9:19 a.m.
Sun, Apr 27	12:49 a.m.	10:21 a.m.
Mon, Apr 28	1:23 a.m.	11:25 a.m.
Mon, May 12	12:13 p.m.	1:14 a.m.
Tue, May 13	1:17 p.m.	1:39 a.m.
Wed, May 14	2:19 p.m.	2:02 a.m.
Thu, May 15	3:20 p.m.	2:24 a.m.
Fri, May 16	4:21 p.m.	2:46 a.m.
Sat, May 17	5:22 p.m.	3:10 a.m.
Sun, May 18	6:23 p.m.	3:37 a.m.
Mon, May 19	7:24 p.m.	4:07 a.m.
Tue, May 20	8:23 p.m.	4:43 a.m.
Wed, May 21	9:17 p.m.	5:26 a.m.
Thu, May 22	10:06 p.m.	6:16 a.m.
Fri, May 23	10:48 p.m.	7:12 a.m.
Sat, May 24	11:23 p.m.	8:13 a.m.
Sun, May 25	11:54 p.m.	9:16 a.m.
Mon, May 26	12:00 a.m.	10:20 a.m.

TEACHING TIP

Do not plan the activity for the last possible date shown in the table. If you do, it might be too cloudy to see the Moon, and there might not be any rain dates available.

Tue, May 27	12:21 a.m.	11:25 a.m.
Wed, Jun 11	1:13 p.m.	12:28 a.m.
Thu, Jun 12	2:14 p.m.	12:51 a.m.
Fri, Jun 13	3:15 p.m.	1:14 a.m.
Sat, Jun 14	4:16 p.m.	1:40 a.m.
Sun, Jun 15	5:17 p.m.	2:09 a.m.
Mon, Jun 16	6:17 p.m.	2:43 a.m.
Tue, Jun 17	7:13 p.m.	3:24 a.m.
Wed, Jun 18	8:03 p.m.	4:12 a.m.
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Mon, Jun 23	10:49 p.m.	9:17 a.m.
Tue, Jun 24	11:13 p.m.	10:21 a.m.
Wed, Jun 25	11:37 p.m.	11:26 a.m.
Thu, Jun 26	12:00 a.m.	12:33 p.m.
Thu, Jul 10	1:06 p.m.	11:42 p.m.
Fri, Jul 11	2:07 p.m.	12:00 a.m.
Sat, Jul 12	3:09 p.m.	12:10 a.m.
Sun, Jul 13	4:09 p.m.	12:42 a.m.
Wed, Jul 16	6:46 p.m.	2:59 a.m.
Thu, Jul 17	7:25 p.m.	3:58 a.m.
Fri, Jul 18	7:59 p.m.	5:01 a.m.
Sat, Jul 19	8:28 p.m.	6:05 a.m.
Sun, Jul 20	8:54 p.m.	7:10 a.m.
Mon, Jul 21	9:18 p.m.	8:14 a.m.
Tue, Jul 22	9:42 p.m.	9:19 a.m.
Wed, Jul 23	10:06 p.m.	10:25 a.m.

Thu, Jul 24	10:33 p.m.	11:33 a.m.
Fri, Jul 25	11:05 p.m.	12:44 p.m.
Sat, Aug 9	1:59 p.m.	11:18 p.m.
Sun, Aug 10	2:58 p.m.	12:00 a.m.
Mon, Aug 11	3:53 p.m.	12:01 a.m.
Tue, Aug 12	4:41 p.m.	12:51 a.m.
Wed, Aug 13	5:23 p.m.	1:47 a.m.
Thu, Aug 14	5:59 p.m.	2:49 a.m.
Fri, Aug 15	6:30 p.m.	3:53 a.m.
Sat, Aug 16	6:58 p.m.	4:59 a.m.
Sun, Aug 17	7:22 p.m.	6:04 a.m.
Mon, Aug 18	7:46 p.m.	7:10 a.m.
Tue, Aug 19	8:11 p.m.	8:17 a.m.
Wed, Aug 20	8:37 p.m.	9:25 a.m.
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Fri, Aug 22	9:43 p.m.	11:48 a.m.
Sat, Aug 23	10:27 p.m.	1:02 p.m.
Mon, Sep 8	2:34 p.m.	11:36 p.m.
Tue, Sep 9	3:19 p.m.	12:00 a.m.
Wed, Sep 10	3:57 p.m.	12:35 a.m.
Thu, Sep 11	4:30 p.m.	1:38 a.m.
Fri, Sep 12	4:58 p.m.	2:43 a.m.
Sat, Sep 13	5:24 p.m.	3:49 a.m.
Sun, Sep 14	5:49 p.m.	4:55 a.m.
Tue, Sep 16	6:40 p.m.	7:11 a.m.
Wed, Sep 17	7:09 p.m.	8:23 a.m.
Thu, Sep 18	7:44 p.m.	9:36 a.m.
Fri, Sep 19	8:26 p.m.	10:51 a.m.
Sat, Sep 20	9:17 p.m.	12:04 p.m.

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Thu, Oct 9	2:57 p.m.	12:26 a.m.
Fri, Oct 10	3:24 p.m.	1:31 a.m.
Sat, Oct 11	3:49 p.m.	2:36 a.m.
Sun, Oct 12	4:14 p.m.	3:42 a.m.
Mon, Oct 13	4:40 p.m.	4:51 a.m.
Tue, Oct 14	5:08 p.m.	6:02 a.m.
Wed, Oct 15	5:41 p.m.	7:16 a.m.
Thu, Oct 16	6:22 p.m.	8:33 a.m.
Fri, Oct 17	7:11 p.m.	9:50 a.m.
Sat, Oct 18	8:11 p.m.	11:01 a.m.
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Mon, Oct 20	10:31 p.m.	12:55 p.m.
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Sun, Nov 16	8:17 p.m.	10:47 a.m.
Mon, Nov 17	9:33 p.m.	11:33 a.m.
Tue, Nov 18	10:45 p.m.	12:10 p.m.
Wed, Nov 19	11:54 p.m.	12:40 p.m.
Sat, Dec 6	12:37 p.m.	12:12 a.m.
Sun, Dec 7	1:02 p.m.	1:17 a.m.
Mon, Dec 8	1:30 p.m.	2:25 a.m.
Tue, Dec 9	2:03 p.m.	3:37 a.m.
Wed, Dec 10	2:44 p.m.	4:53 a.m.
Thu, Dec 11	3:35 p.m.	6:11 a.m.
Fri, Dec 12	4:39 p.m.	7:25 a.m.

Sat, Dec 13	5:52 p.m.	8:30 a.m.
Sun, Dec 14	7:10 p.m.	9:23 a.m.
Mon, Dec 15	8:27 p.m.	10:06 a.m.
Tue, Dec 16	9:41 p.m.	10:40 a.m.
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Thu, Dec 18	11:56 p.m.	11:34 a.m.
Fri, Dec 19	12:00 a.m.	11:58 a.m.

Moon Visibility Table
2009

The following table shows the dates and times when the Moon will be optimally visible in Washington, D.C., to perform Activity 2. The times for optimal visibility in the continental USA are similar (though they vary somewhat).

You can find the altitude of the Moon, as well as moonrise and moonset times for your exact location, at the U.S. Naval Observatory Astronomical Applications Department's Data Services web site: http://aa.usno.navy.mil/data/

The table show the date, rise time, and set time of the Moon when it is at least half full (no crescents), to make sure the Moon fills enough of the Moon-viewer cut-out to make the measurement accurate. Note that in most cases, the rise time is after the set time. This is because the Moon (when it is at least half full) is usually visible at midnight, and then it will set during the day, but rise again at night.

Date	Moon Rise	Moon Set
Mon, Jan 5	11:58 a.m.	1:18 a.m.
Tue, Jan 6	12:34 p.m.	2:30 a.m.
Wed, Jan 7	1:18 p.m.	3:44 a.m.
Thu, Jan 8	2:14 p.m.	4:58 a.m.
Fri, Jan 9	3:22 p.m.	6:08 a.m.
Sat, Jan 10	4:38 p.m.	7:07 a.m.
Sun, Jan 11	5:58 p.m.	7:55 a.m.
Mon, Jan 12	7:15 p.m.	8:34 a.m.
Tue, Jan 13	8:29 p.m.	9:06 a.m.
Wed, Jan 14	9:39 p.m.	9:34 a.m.
Thu, Jan 15	10:46 p.m.	9:59 a.m.
Fri, Jan 16	11:51 p.m.	10:24 a.m.
Sat, Jan 17	12:00 a.m.	10:50 a.m.
Tue, Feb 3	11:11 a.m.	1:28 a.m.
Wed, Feb 4	12:00 p.m.	2:40 a.m.
Thu, Feb 5	1:00 p.m.	3:49 a.m.
Fri, Feb 6	2:10 p.m.	4:51 a.m.
Sat, Feb 7	3:27 p.m.	5:43 a.m.
Sun, Feb 8	4:45 p.m.	6:26 a.m.
Mon, Feb 9	6:02 p.m.	7:01 a.m.
Tue, Feb 10	7:15 p.m.	7:31 a.m.
Wed, Feb 11	8:25 p.m.	7:58 a.m.
Thu, Feb 12	9:33 p.m.	8:24 a.m.
Fri, Feb 13	10:39 p.m.	8:50 a.m.
Sat, Feb 14	11:44 p.m.	9:17 a.m.
Sun, Feb 15	12:00 a.m.	9:48 a.m.
Mon, Feb 16	12:48 a.m.	10:23 a.m.
Thu, Mar 5	11:56 a.m.	2:42 a.m.
Fri, Mar 6	1:08 p.m.	3:36 a.m.
Sat, Mar 7	2:23 p.m.	4:20 a.m.
Sun, Mar 8	3:38 p.m.	4:57 a.m.
Mon, Mar 9	4:51 p.m.	5:29 a.m.
Tue, Mar 10	6:02 p.m.	5:57 a.m.
Wed, Mar 11	7:11 p.m.	6:23 a.m.
Thu, Mar 12	8:19 p.m.	6:49 a.m.
Fri, Mar 13	9:26 p.m.	7:16 a.m.
Sat, Mar 14	10:31 p.m.	7:46 a.m.
Sun, Mar 15	11:35 p.m.	8:19 a.m.
Mon, Mar 16	12:00 a.m.	8:58 a.m.

Tue, Mar 17	12:35 a.m.	9:43 a.m.
Wed, Mar 18	1:29 a.m.	10:33 a.m.
Fri, Apr 3	12:11 p.m.	2:19 a.m.
Sat, Apr 4	1:24 p.m.	2:57 a.m.
Sun, Apr 5	2:36 p.m.	3:30 a.m.
Mon, Apr 6	3:46 p.m.	3:58 a.m.
Tue, Apr 7	4:54 p.m.	4:24 a.m.
Wed, Apr 8	6:01 p.m.	4:50 a.m.
Thu, Apr 9	7:08 p.m.	5:16 a.m.
Fri, Apr 10	8:14 p.m.	5:45 a.m.
Sat, Apr 11	9:19 p.m.	6:17 a.m.
Sun, Apr 12	10:21 p.m.	6:53 a.m.
Mon, Apr 13	11:18 p.m.	7:36 a.m.
Tue, Apr 14	12:00 a.m.	8:25 a.m.
Wed, Apr 15	12:08 a.m.	9:19 a.m.
Thu, Apr 16	12:52 a.m.	10:17 a.m.
Fri, Apr 17	1:29 a.m.	11:17 a.m.
Sat, May 2	12:28 p.m.	1:32 a.m.
Sun, May 3	1:37 p.m.	2:01 a.m.

Mon, May 4	2:44 p.m.	2:28 a.m.
Tue, May 5	3:50 p.m.	2:53 a.m.
Wed, May 6	4:55 p.m.	3:18 a.m.
Thu, May 7	6:01 p.m.	3:46 a.m.
Fri, May 8	7:06 p.m.	4:16 a.m.
Sat, May 9	8:09 p.m.	4:51 a.m.
Sun, May 10	9:08 p.m.	5:31 a.m.
Mon, May 11	10:01 p.m.	6:18 a.m.
Tue, May 12	10:47 p.m.	7:10 a.m.
Wed, May 13	11:26 p.m.	8:07 a.m.
Thu, May 14	11:59 p.m.	9:06 a.m.
Fri, May 15	12:00 a.m.	10:07 a.m.
Sat, May 16	12:28 a.m.	11:07 a.m.
Sun, May 17	12:54 a.m.	12:08 p.m.
Sun, May 31	12:37 p.m.	12:31 a.m.
Mon, Jun 1	1:43 p.m.	12:57 a.m.
Tue, Jun 2	2:48 p.m.	1:22 a.m.
Wed, Jun 3	3:53 p.m.	1:49 a.m.
Thu, Jun 4	4:57 p.m.	2:18 a.m.

TEACHING TIP

Do not plan the activity for the last possible date shown in the table. If you do, it might be too cloudy to see the Moon, and there might not be any rain dates available.

Fri, Jun 5	6:00 p.m.	2:51 a.m.
Sat, Jun 6	7:00 p.m.	3:29 a.m.
Sun, Jun 7	7:55 p.m.	4:13 a.m.
Mon, Jun 8	8:43 p.m.	5:04 a.m.
Tue, Jun 9	9:24 p.m.	5:59 a.m.
Wed, Jun 10	10:00 p.m.	6:58 a.m.
Thu, Jun 11	10:30 p.m.	7:58 a.m.
Fri, Jun 12	10:56 p.m.	8:58 a.m.
Sat, Jun 13	11:20 p.m.	9:58 a.m.
Sun, Jun 14	11:43 p.m.	10:57 a.m.
Mon, Jun 15	12:00 a.m.	11:58 a.m.
Tue, Jun 30	1:45 p.m.	12:00 a.m.
Wed, Jul 1	2:50 p.m.	12:20 a.m.
Thu, Jul 2	3:53 p.m.	12:52 a.m.
Fri, Jul 3	4:54 p.m.	1:28 a.m.
Sat, Jul 4	5:50 p.m.	2:10 a.m.
Sun, Jul 5	6:40 p.m.	2:59 a.m.
Mon, Jul 6	7:24 p.m.	3:53 a.m.
Tue, Jul 7	8:01 p.m.	4:51 a.m.
Wed, Jul 8	8:32 p.m.	5:51 a.m.
Thu, Jul 9	9:00 p.m.	6:51 a.m.
Fri, Jul 10	9:25 p.m.	7:51 a.m.
Sat, Jul 11	9:48 p.m.	8:50 a.m.
Sun, Jul 12	10:10 p.m.	9:50 a.m.
Mon, Jul 13	10:34 p.m.	10:50 a.m.
Tue, Jul 14	11:00 p.m.	11:53 a.m.
Wed, Jul 15	11:30 p.m.	12:59 p.m.
Wed, Jul 29	1:45 p.m.	11:28 p.m.
Thu, Jul 30	2:47 p.m.	12:00 a.m.

Fri, Jul 31	3:45 p.m.	12:09 a.m.
Sat, Aug 1	4:37 p.m.	12:55 a.m.
Sun, Aug 2	5:23 p.m.	1:47 a.m.
Mon, Aug 3	6:02 p.m.	2:44 a.m.
Tue, Aug 4	6:35 p.m.	3:43 a.m.
Wed, Aug 5	7:04 p.m.	4:44 a.m.
Thu, Aug 6	7:30 p.m.	5:44 a.m.
Fri, Aug 7	7:53 p.m.	6:44 a.m.
Sat, Aug 8	8:16 p.m.	7:44 a.m.
Sun, Aug 9	8:39 p.m.	8:44 a.m.
Mon, Aug 10	9:04 p.m.	9:45 a.m.
Tue, Aug 11	9:32 p.m.	10:49 a.m.
Wed, Aug 12	10:05 p.m.	11:55 a.m.
Thu, Aug 13	10:45 p.m.	1:04 p.m.
Fri, Aug 28	2:32 p.m.	11:41 p.m.
Sat, Aug 29	3:20 p.m.	12:00 a.m.
Sun, Aug 30	4:01 p.m.	12:36 a.m.
Mon, Aug 31	4:36 p.m.	1:35 a.m.
Tue, Sep 1	5:07 p.m.	2:35 a.m.
Wed, Sep 2	5:33 p.m.	3:36 a.m.
Thu, Sep 3	5:58 p.m.	4:36 a.m.
Fri, Sep 4	6:21 p.m.	5:36 a.m.
Sat, Sep 5	6:45 p.m.	6:37 a.m.
Sun, Sep 6	7:09 p.m.	7:38 a.m.
Mon, Sep 7	7:36 p.m.	8:42 a.m.
Tue, Sep 8	8:08 p.m.	9:48 a.m.
Wed, Sep 9	8:45 p.m.	10:55 a.m.
Thu, Sep 10	9:31 p.m.	12:03 p.m.
Fri, Sep 11	10:26 p.m.	1:09 p.m.

Sat, Sep 26	1:58 p.m.	11:25 p.m.
Sun, Sep 27	2:35 p.m.	12:00 a.m.
Mon, Sep 28	3:07 p.m.	12:25 a.m.
Tue, Sep 29	3:35 p.m.	1:25 a.m.
Wed, Sep 30	4:01 p.m.	2:25 a.m.
Thu, Oct 1	4:24 p.m.	3:25 a.m.
Fri, Oct 2	4:48 p.m.	4:26 a.m.
Sat, Oct 3	5:13 p.m.	5:28 a.m.
Sun, Oct 4	5:39 p.m.	6:31 a.m.
Mon, Oct 5	6:10 p.m.	7:37 a.m.
Tue, Oct 6	6:46 p.m.	8:46 a.m.
Wed, Oct 7	7:30 p.m.	9:55 a.m.
Thu, Oct 8	8:22 p.m.	11:02 a.m.
Fri, Oct 9	9:24 p.m.	12:03 p.m.
Sat, Oct 10	10:33 p.m.	12:57 p.m.
Sun, Oct 11	11:45 p.m.	1:43 p.m.
Mon, Oct 26	1:35 p.m.	12:00 a.m.
Tue, Oct 27	2:01 p.m.	12:13 a.m.
Wed, Oct 28	2:26 p.m.	1:12 a.m.
Thu, Oct 29	2:49 p.m.	2:12 a.m.
Fri, Oct 30	3:13 p.m.	3:13 a.m.
Sat, Oct 31	3:39 p.m.	4:16 a.m.
Sun, Nov 1	4:09 p.m.	5:21 a.m.
Mon, Nov 2	4:43 p.m.	6:30 a.m.
Tue, Nov 3	5:25 p.m.	7:40 a.m.
Wed, Nov 4	6:16 p.m.	8:50 a.m.
Thu, Nov 5	7:17 p.m.	9:55 a.m.
Fri, Nov 6	8:25 p.m.	10:53 a.m.
Sat, Nov 7	9:37 p.m.	11:42 a.m.

Sun, Nov 8	10:50 p.m.	12:22 p.m.
Mon, Nov 9	12:00 a.m.	12:56 p.m.
Wed, Nov 25	12:50 p.m.	12:00 a.m.
Thu, Nov 26	1:13 p.m.	12:58 a.m.
Fri, Nov 27	1:38 p.m.	1:59 a.m.
Sat, Nov 28	2:05 p.m.	3:02 a.m.
Sun, Nov 29	2:37 p.m.	4:08 a.m.
Mon, Nov 30	3:16 p.m.	5:18 a.m.
Tue, Dec 1	4:03 p.m.	6:29 a.m.
Wed, Dec 2	5:01 p.m.	7:38 a.m.
Thu, Dec 3	6:09 p.m.	8:41 a.m.
Fri, Dec 4	7:22 p.m.	9:35 a.m.
Sat, Dec 5	8:38 p.m.	10:20 a.m.
Sun, Dec 6	9:52 p.m.	10:57 a.m.
Mon, Dec 7	11:04 p.m.	11:29 a.m.
Tue, Dec 8	12:00 a.m.	11:57 a.m.
Fri, Dec 25	12:04 p.m.	12:46 a.m.
Sat, Dec 26	12:33 p.m.	1:49 a.m.
Sun, Dec 27	1:07 p.m.	2:55 a.m.
Mon, Dec 28	1:49 p.m.	4:04 a.m.
Tue, Dec 29	2:41 p.m.	5:14 a.m.
Wed, Dec 30	3:44 p.m.	6:21 a.m.
Thu, Dec 31	4:57 p.m.	7:20 a.m.

Teacher Answer Key

Student Worksheet 1

Part III

1. Answers will vary depending on the length of the tube. Most tubes are 28 cm (280 mm), yielding an image size of 2.6 millimeters.

2. Answers will vary depending on the length of the tube. Most tubes are 28 cm (280 mm).

3. Tube length/ image width = 280 mm/ 2.6 mm = 107*

5. See Data Table below.

6. 107*, or the same number you calculated in Question 3.

* The number of Suns that could fit between the Earth and the Sun actually varies from 106-109 during the year, due to the fact that the Earth's orbit is not a perfect circle.

Table	Little Triangle	Big Triangle
Where is the point of the triangle?	At the pinhole.	At the pinhole.
What forms the base of the triangle?	The diameter of the model Sun.	The diameter of the real Sun.
What is the length of the triangle?	The length of the tube.	The distance between the real Sun and the real Earth.
How many bases fit along the length of the triangle?	About 107.	About 107.
What did you figure out?	The number of model Suns that fit along the length of the tube.	The number of real Suns that fit between the real Earth and the real Sun.
What did you use as a ruler?	The model Sun.	The real Sun.

Questions

1. The image is not a very detailed model of the Sun, so it limits what we can learn about the Sun. Nevertheless, it is all we need to find the distance to the Sun.

2. 

3. The Earth does not orbit the Sun in a perfect circle, so the Sun-Earth distance changes slightly.

4. $\frac{\text{Your Shadow (2')}}{\text{Your Height (4')}}$ = 0.5; 0.5 x Height of Flagpole (12′) = 6′

   So the flagpole's shadow is 6′.

5. 1,400,000 x 107 (or answer to Part III, Question 5) = 150,000,000 km

6. Answers will vary.

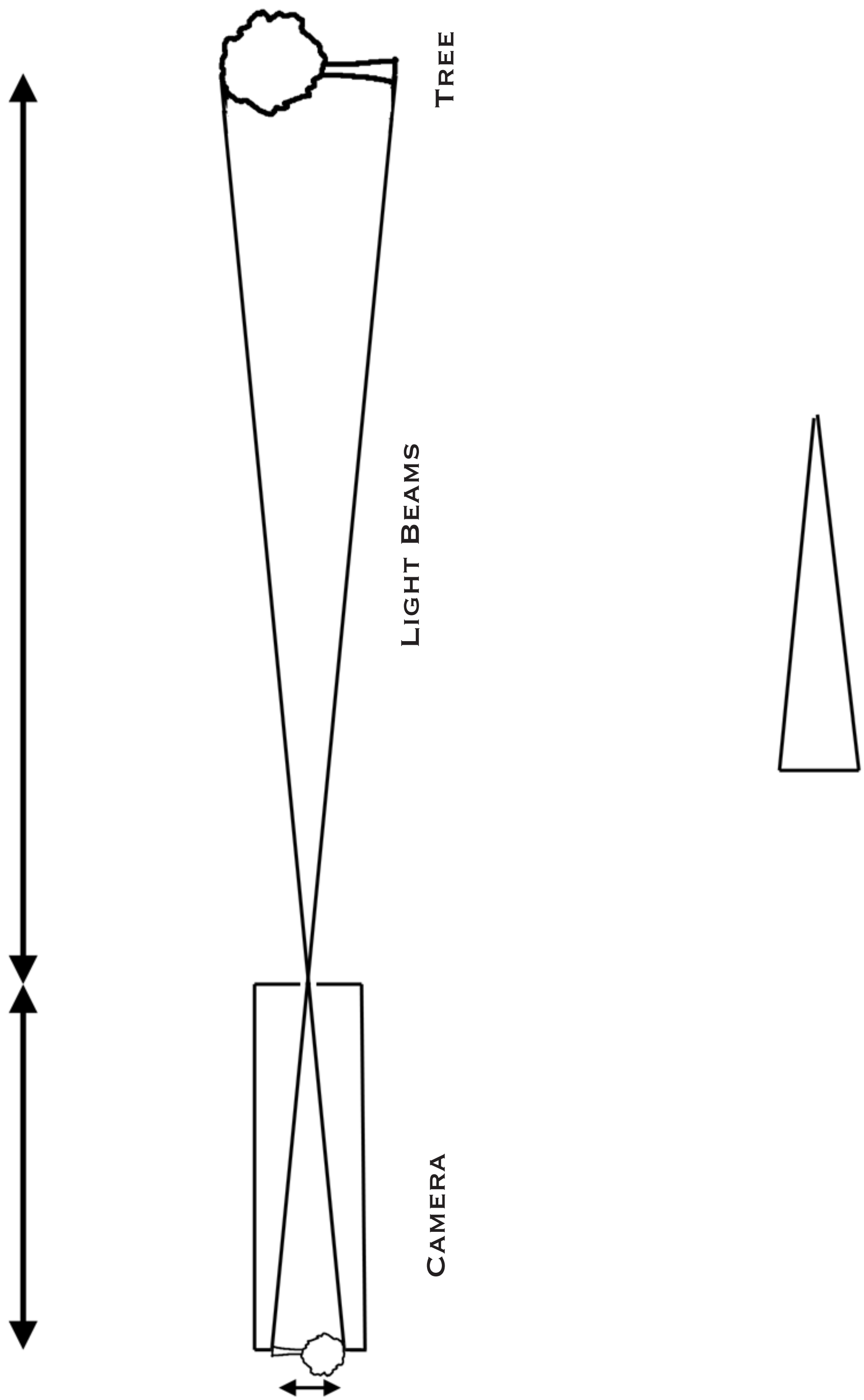
Student Worksheet 2

Data Table

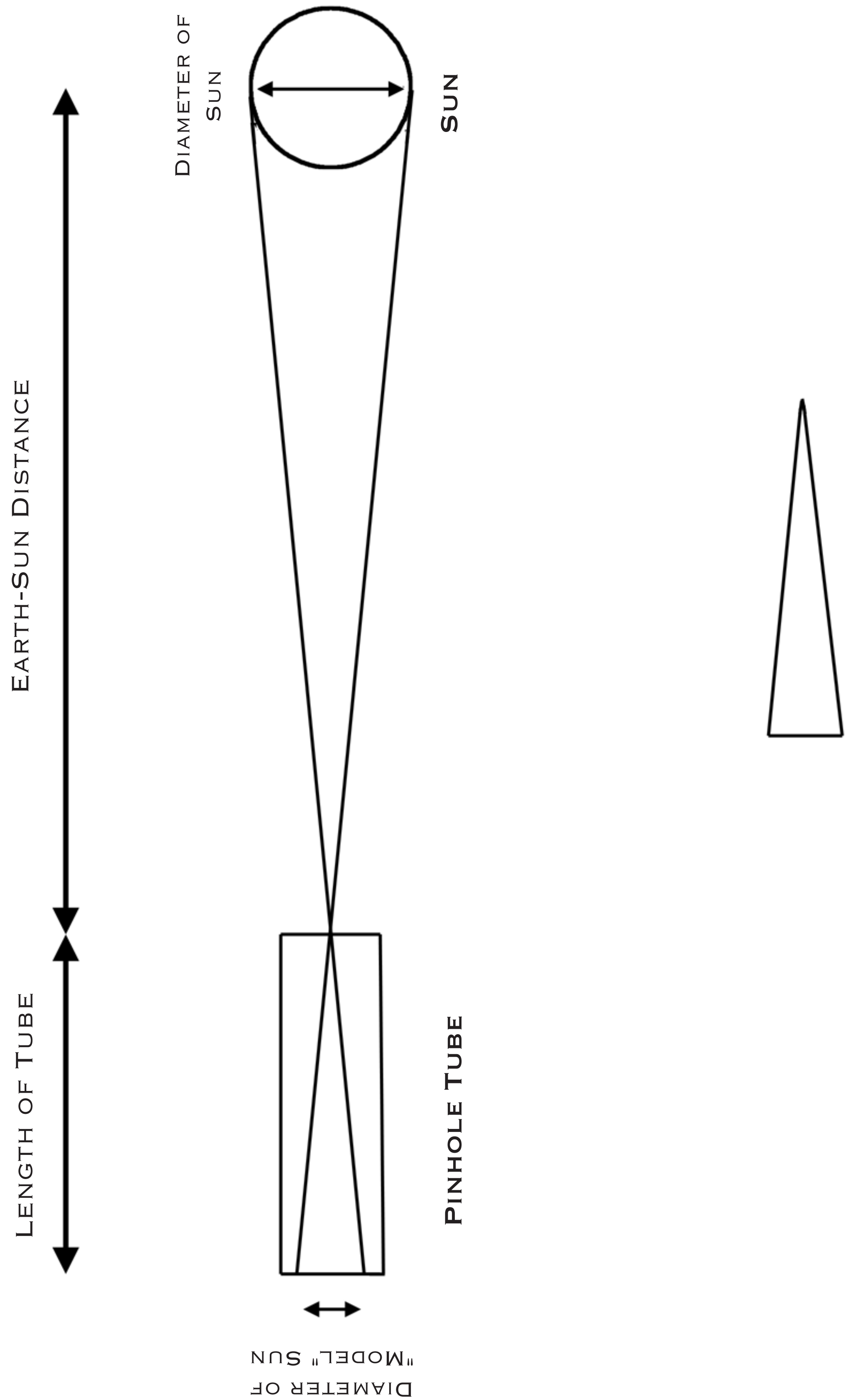
Table	Little Triangle	Big Triangle
Where is the point of the triangle?	At my eye.	At my eye..
What forms the base of the triangle?	The diameter of the Moon-viewer cut-out (2 cm).	The diameter of the real Moon.
What is the length of the triangle?	The distance between my eye and the Moon-viewer.	The distance between the real Earth and the real Moon.
How many bases fit along the length of the triangle?	About 107 (length of string / 2 cm).	About 107.
What did you figure out?	The number of model Moons that would fit along the length of the string.	The number of real Moons that fit between your eye and the real Moon.
What did you use as a ruler?	The model Moon.	The real Moon.

7. About 107.

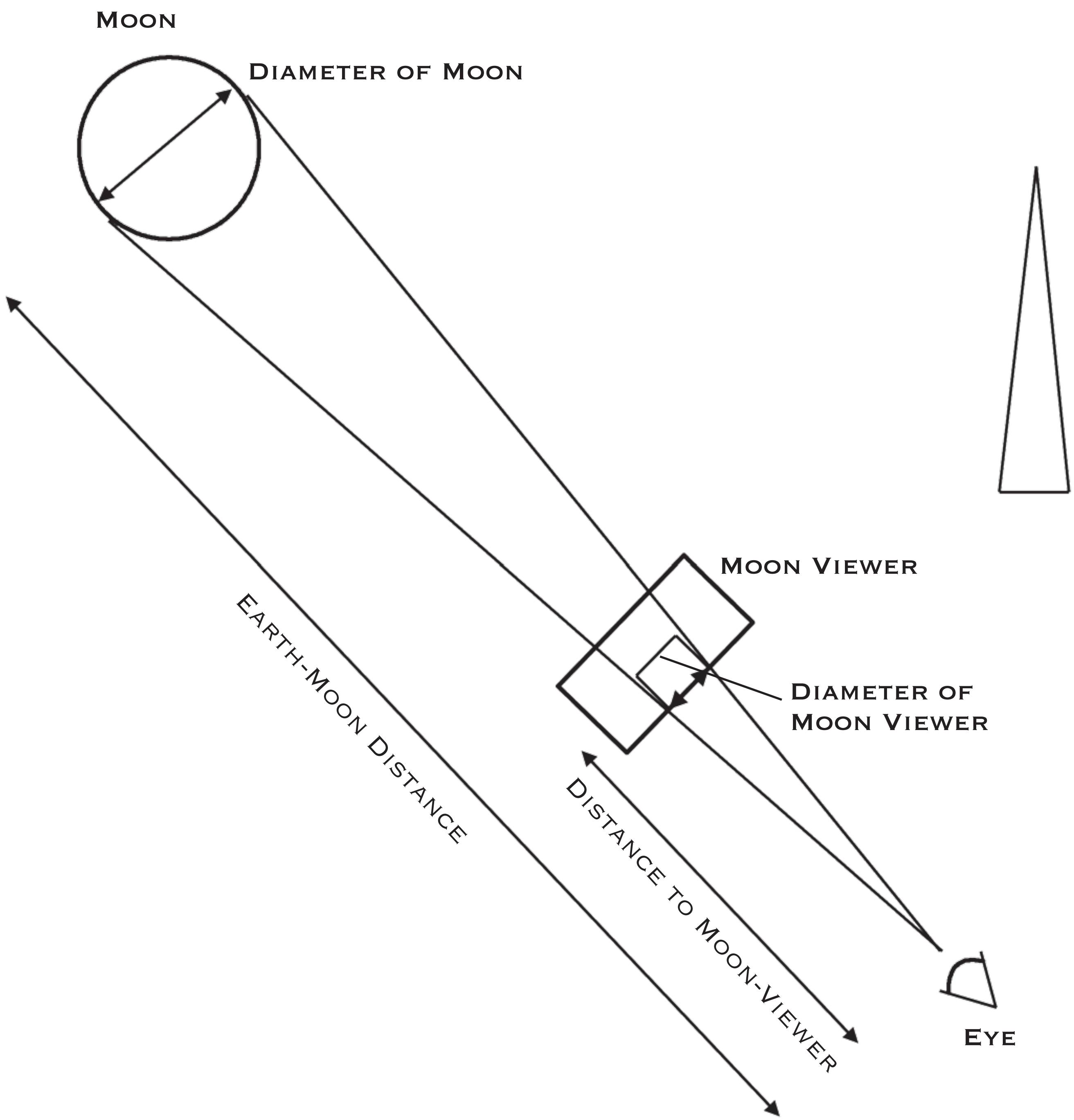
Tree Transparency



Sun Transparency



MOON TRANSPARENCY

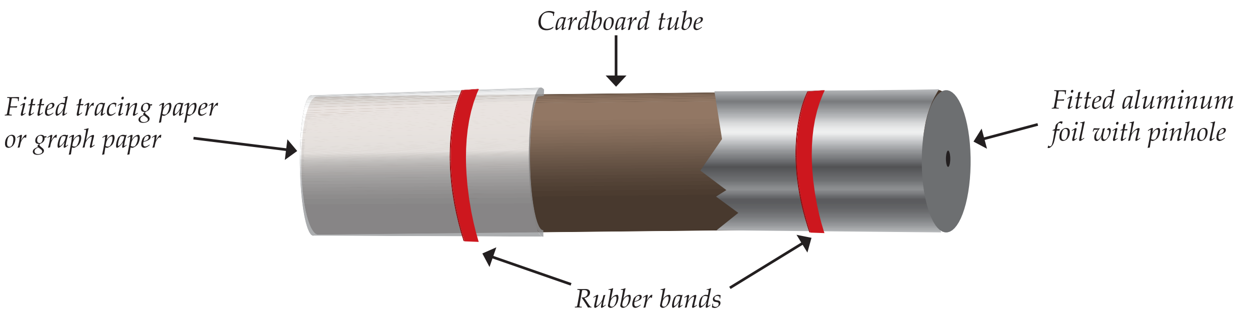


STUDENT WORKSHEET 1: SUN—RULER OF THE SOLAR SYSTEM

NAME ____ DATE ____________

In this activity, you will measure the distance from the schoolyard to the Sun. You will use the pinhole tube, which you will make in Part I.

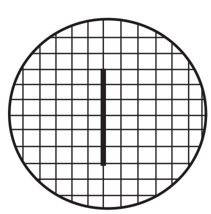
PART I: BUILDING YOUR PINHOLE TUBE



STUDENT MATERIALS (PER PAIR):

- Cardboard paper towel tube
- Aluminum foil square (10 cm x 10 cm)
- Graph paper square (10 cm x 10 cm)
- 2 rubber bands
- Thumbtack or pin
- Metric ruler
- Sharp pencil
- Meter stick
- Masking tape
- Optional: Calculator
- Optional: Markers, stickers, other materials to decorate pinhole tube

1. Decorate your paper towel tube.
2. Place the aluminum foil square over one end of the tube and secure with a rubber band, as shown in the picture.
3. Place the graph paper over the other end and secure with a rubber band.
4. Use a thumbtack or push pin to carefully poke a small hole in the center of the aluminum foil.
5. Create a guideline on the graph paper by gently marking one of the lines near the center of the tube with your pencil. See figure below.



CONSTRUCTION TIP

The smaller your pinhole is, the better your pinhole tube will work. The foil rips easily, so be careful. If it does rip, get a new square of foil and try again. If the hole is not perfectly round, your pinhole tube will not work.

JOURNEY through the UNIVERSE

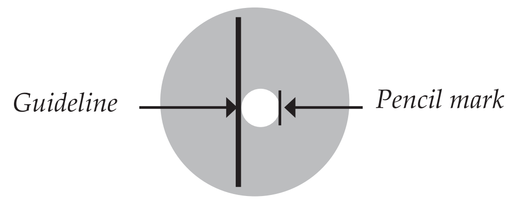
Part II: Using Your Pinhole Tube

1. Go outside with your partner. Take the pinhole tube, pencil, masking tape, and a meter stick with you. Decide who will be in charge of the meter stick, and who will be in charge of the pinhole tube.
2. One of you should hold the meter stick like a pole. The other should sit on the ground and aim the foil end of the tube at the Sun.

WARNING!
Do NOT look directly at the Sun or use the pinhole tube like a telescope!
Looking directly at the Sun will cause permanent eye damage!

3. Move the tube until you see a small image of the Sun on the graph paper. It looks like a circle of light, but it is really a model of the Sun!
4. Tape the tube to the meter stick to stabilize it.
5. Adjust the tube until one side of the Sun's image lines up with your guide line on the graph paper. Hold the tube steady and gently mark the other side of the Sun's image.

Have patience! It is not easy to hold the pinhole tube still and keep the Sun lined up with the guideline.



Part III: Measuring the Distance to the Sun

1. Use your ruler to measure the distance between your guideline and the pencil mark on the graph paper in millimeters.

   How big is the model Sun? _________________mm

2. Measure the length of your pinhole tube in millimeters.

   How long is your tube? ______________________mm

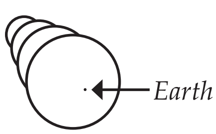
3. Use the model Sun as a ruler. How many model Suns span the length of the tube? (Hint: Divide the length of the tube by the width of the image.)

4. Look at the diagram below and find the triangles. The little triangle inside the pinhole tube is a model of the big triangle. These two triangles are similar triangles: their angles are identical and their sides are proportional.

5. Fill in the table. Since we have similar triangles and the little triangle is a model of the big triangle, can you fill in the table for the big triangle? (Hint: The first entry has been done for you. Remember, a model is proportional to the real object.)

Table	Little Triangle	Big Triangle
Where is the point of the triangle?		At the pinhole.
What forms the base of the triangle?		
What is the length of the triangle?		
How many bases fit along the length of the triangle?		
What did you figure out?		
What did you use as a ruler?		

6. Congratulations! You have now used the real Sun as a ruler. How many real Suns fit between the pinhole tube and the Sun?



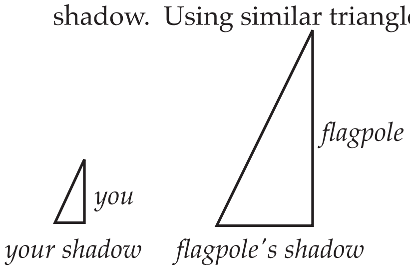
Questions

1. Is the image of the Sun a good model of the real Sun? Why or why not?

2. Imagine the Moon was blocking part of the Sun's light, creating a partial solar eclipse. What would the image on the graph paper look like?

3. If you did the experiment at different times of the year, the answers in the table would vary. Why?

4. Imagine you are 4' tall and are casting a 2' shadow on a sunny day. Next to you is a 12' flagpole that is also casting a shadow. Using similar triangles, figure out the length of the flagpole's shadow.



5. The Sun is 1,400,000 kilometers in diameter. How far away is the Sun from the Earth in kilometers?

6. Research the actual distance from the Earth to the Sun and check your answer from question number 5. Calculate your percent error.

   $$\text{Percent Error} = \frac{\text{Your Answer} - \text{Actual Answer} \ * \ 100}{\text{Actual Answer}}$$

Student Worksheet 2: A Model Moon

Name ______________________________ Date __________

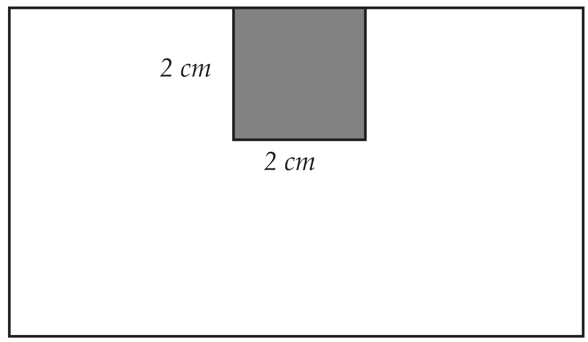
In this activity, you will create a Moon-viewer and determine the distance to the Moon.

Student Materials (per student):

- Student Worksheet 2
- Index card
- Transparent tape
- 3 meters of string
- Metric ruler
- Scissors

Part I: Creating the Moon-viewer

Cut a square in the top edge of an index card, with a length of 2 cm. Be careful in measuring and cutting the shape to ensure an accurate measurement.



Part II: Using your Moon-viewer

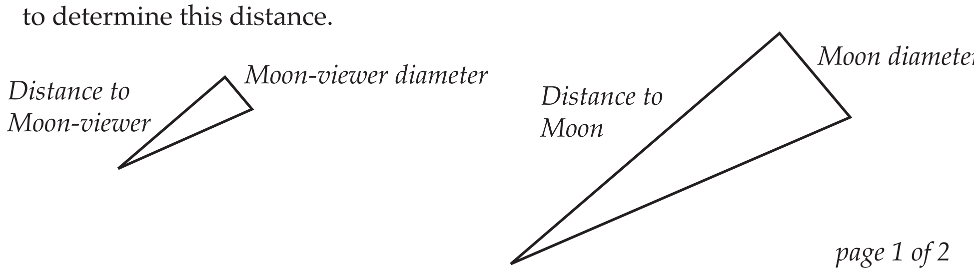
1. Use tape to attach the end of a 3-meter-long string to the bottom center of the Moon-viewer.
2. Tape the card to a window through which you can view the Moon.
3. Look at the Moon through the cutout of your Moon-viewer while holding the string up to your eye level.
4. Slowly adjust your distance from the Moon-viewer and let the string slide through your fingers to keep it taut. You have reached the correct distance when the Moon appears to just fill the cutout.
5. Mark the location of your eye on the string with an ink pen. Then, measure the distance, in centimeters, from the Moon-viewer to your eye along the taut string. Record the measurement in the Data Table on the next page.
6. Determine the distance to the Moon using similar triangles. Refer to the diagram below, and measurements you have already made, to fill in the data table to determine this distance.

Tip

If you do not have a Moon-facing window, you may choose to mount the index card on a stick or other temporary device and perform the activity outdoors.

Tip

If the Moon is not full, it will not fill the whole cut-out, just part of it. In this case, rotate the Moon-viewer so the tallest part of the Moon fits the length of the square.



JOURNEY through the UNIVERSE

Data Table		
Table	Little Triangle	Big Triangle
Where is the point of the triangle?		At my eye.
What forms the base of the triangle?		
What is the length of the triangle?		
How many bases fit along the length of the triangle?		
What did you figure out?		
What did you use as a ruler?		

7. You have now used the real Moon as a ruler. How many real Moons would fit between you and the Moon?