

Introducing the Sun-Earth-Moon System



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Earth from above the Moon's horizon as seen by astronaut Michael Collins in the Apollo 11 Moon orbiter Columbia.

INTRODUCTION

You probably have witnessed the beauty of the Sun as it appears to rise over the horizon. You may have noticed that the Moon appears to change shape each night of the month. These events and others can tell us much about the Sun-Earth-Moon system.

In this lesson, you will examine the relative sizes and distances of the Sun, Earth, and Moon, and how these three bodies interact within our solar system. First, you will work with your group to demonstrate what you know about the Sun-Earth-Moon system using model spheres. Then you will compare your group's ideas with those of other groups. In the second inquiry, you will compare the size of the Sun, Earth, and Moon and their distances from one another. This helps you prepare for later lessons in this module.

OBJECTIVES FOR THIS LESSON

Demonstrate what you know about the Sun-Earth-Moon system using simple models.

Examine the diameters of the Sun, Earth, and Moon, and their relative distances from each other.

Compare the relative distances between two objects based on their apparent and true diameters.

Record the times at which the Moon rises and sets, and observe its appearance over a one- to two-week period.

Getting Started

- 1.** How many stars do you think are in our solar system? Discuss your ideas with the class.
- 2.** Read “Folklore: Making Sense of the Skies.” Share with the class your thoughts on the reading selection and your answers to the questions at the end of the reader.

MATERIALS FOR LESSON 2

For your group

- 1 transparency
- 1 set of fine-point transparency markers
- 1 white sphere, 7.5 centimeters (cm)
- 1 white sphere, 3.5 cm
- 1 marble, 1 cm
- 1 globe of Earth, 12 cm
- 1 flashlight
- 2 D-cell batteries
- 1 metric measuring tape

Inquiry 2.1

Demonstrating What We Know About the Sun-Earth-Moon System

PROCEDURE

- 1.** Divide a page in your science notebook into four sections (quadrants). Use both words and labeled pictures in each section to record four things you know about the Sun-Earth-Moon system. For example, you may want to illustrate how these three solar system bodies are positioned, or describe how they move relative to one another.
- 2.** Use the materials in the plastic box as models of the Sun, Earth, and Moon to demonstrate to your group one thing that you recorded about the Sun-Earth-Moon system. One member of your group will record your idea on the transparency. Have each member of your group contribute one idea.

REFLECTING ON WHAT YOU'VE DONE

- 1.** Use the transparency and models to demonstrate to the class one thing that your group knows about the Sun, Earth, and Moon.
- 2.** In your science notebook, write about something new that you learned in this lesson.
- 3.** On the basis of your class discussions, record in your science notebook the difference between the terms “rotation” and “revolution.” Which word means the same as “orbit?” Feel free to use examples. Record your responses in both words and pictures, and label your diagrams. You will return to the meanings of these terms in Lessons 3 and 4.

Inquiry 2.2

Scaling the Sun-Earth-Moon System

PROCEDURE

1. Do you think that the size of the sphere that you selected for your Moon was to scale with the size of the 12-cm globe of Earth? How big would a model Sun have to be in order to be to scale with your 12-cm Earth? Share your ideas with the class and explain your answers.

2. Read “Scaling the Sun-Earth-Moon System” in this lesson. As you read, answer the following questions in your notebook:

A. What is the diameter of Earth at the equator?

B. What is the diameter of the Moon?

C. What mathematical equation describes how many times smaller in diameter the Moon is than Earth?

D. What is the distance from Earth to the Moon?

E. What mathematical equation describes how to measure the distance from Earth to the Moon using Earth’s diameter as a unit of measure?

F. What is the diameter of the Sun?

G. What mathematical equation describes how many Earth diameters equal the Sun’s diameter?

H. Why does the Sun appear to be the same size as the Moon in the sky? What mathematical equation would you use to explain why the Sun and the Moon appear to be the same size?

I. Why is there a leap year every four years?

J. Use the reading selection to help you decide if the diameter of the model Moon you used in Inquiry 2.1 is to scale with your 12-cm globe of Earth.

K. How large would your model Sun be if scaled to your 12-cm Earth?

REFLECTING ON WHAT YOU’VE DONE

1. Share with the class what you learned about the Sun, Earth, and Moon from the reading selection.

2. How far away would your model Sun be if scaled to your model Moon and Earth? Watch as someone in your class demonstrates this.

3. Return to your notebook entries showing the four quadrants. Is there anything that you want to change or add to reflect your new thinking? Add that information now.

FOLKLORE

Making Sense of the Skies

How did ancient people explain the apparent changes in the shape of the Moon or the rising and setting Sun? They didn't have all the scientific information we have today, yet they wanted to make sense of the mysteries around them.

The ancient Greeks, for example, wondered about the strange light that fell on Earth at night. They didn't know that it was light from the Sun reflected off the Moon. Instead, they believed that Artemis, their goddess of the Moon, rode her chariot across the sky and shot silver arrows to Earth. Those silver arrows created the mysterious light we know as moonlight.

Phases of the Moon

The moon often appears to change its shape. These "phases" of the Moon confounded the ancients. They didn't understand that the changing positions of the Moon in relation to Earth caused different parts of the illuminated Moon to be visible from Earth. They didn't know that the Moon never really changes shape.

To make sense of this mystery, ancient Hindus believed that the Moon held a special drink that only gods could consume. As the gods drank the special liquid, the Moon shrank. When the gods refilled the Moon with their special drink, it became full again.

An old story that is still recounted by the Inuits of Greenland explains the Moon's phases this way: The Moon god, Anningan, continually chases his sister, the Sun goddess Malina, across the sky. During the chase, he forgets to eat and grows thinner and thinner. To satisfy his hunger, he disappears for three days each month (during the new moon) and then returns to chase his sister again.

The Day-Night Cycle

The continuous cycle of day and night spawned many fascinating tales. The Mamaiurans, an Amazon tribe in Brazil, say that at the beginning of time so many birds lived in the sky that their wings blocked the Sun's light, making it always nighttime. Because of that, the people feared attacks from wild animals.

Tired of the darkness, Mamaiuran brothers Iae and Kuat decided to force the king of the birds, Urubutsin, to share some of the daylight. The two brothers hid inside a dead animal and waited for Urubutsin. When the Bird King came close, Kuat grabbed his leg and held him until he agreed to share daylight with the people of the Amazon. That, according to Mamaiuran legend, is why day alternates with night.

An ancient Japanese legend explained sunlight another way. The Sun goddess, Amaterasu, had



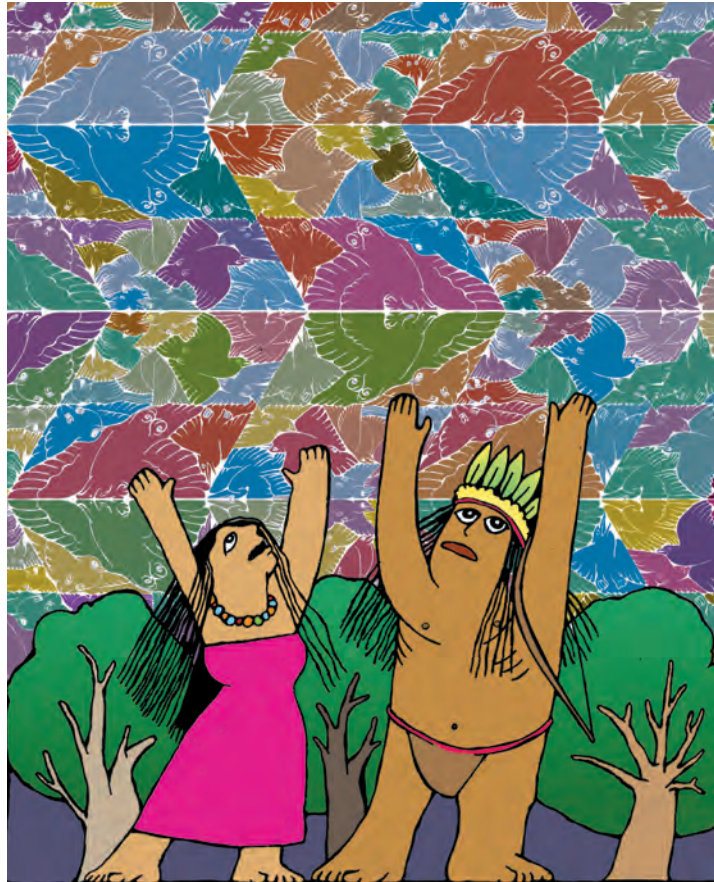
In this painting of Father Sky and Mother Earth, the Navajo included patterns of constellations.

SMITHSONIAN INSTITUTION, NATIONAL ANTHROPOLOGICAL ARCHIVES

a younger brother, Sunsanoo, who was a mischievous god of storms. One day he destroyed Amaterasu's beautiful garden. Deeply saddened, Amaterasu hid in a dark cave, plunging the world into darkness and causing all life to wither and die. Amaterasu was eventually drawn out of the cave by the music and dancing of another goddess. The other gods hung a mirror that reflected to Amaterasu her own dazzling beauty and light. She returned to her throne to warm and light the world and nurture life. □

QUESTIONS

1. Why did people tell tales like these?
2. According to Chinese mythology, a white hare is believed to live on the Moon, which is carried by a dragon. Write a creative story to explain this myth.



Legend has it that so many birds lived in the sky, their wings blocked the Sun's light.

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This woodcut shows Amaterasu, the Japanese Sun goddess.

Scaling the Sun-Earth-Moon System

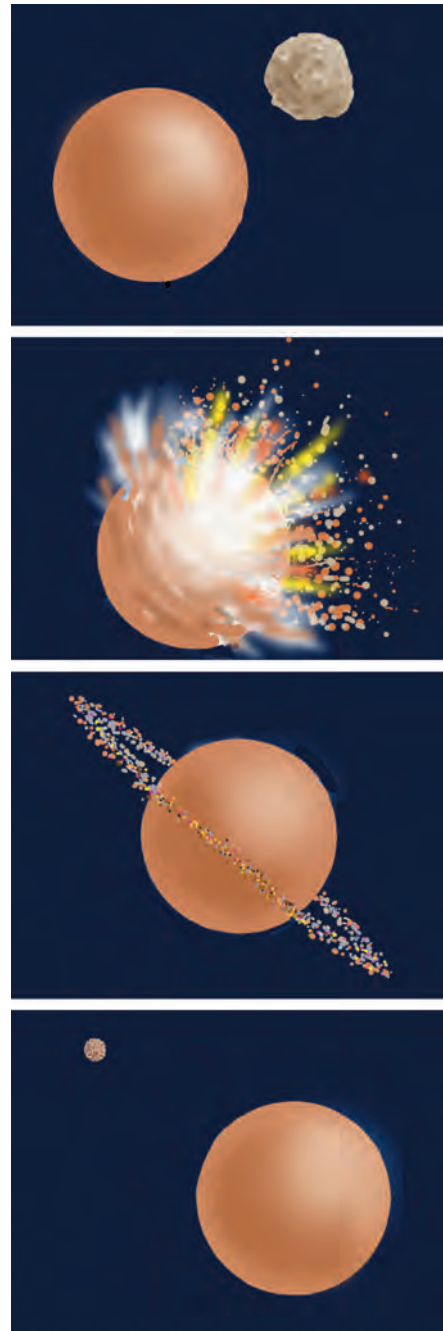
Earth's Moon

The Moon's age is estimated to be between 4.3 billion and 4.5 billion years. There are many theories about how the Moon was formed. Some astronomers think the Moon may have been formed when a Mars-sized asteroid collided with Earth about 100 million to 200 million years after Earth was formed approximately 4.5 billion years ago. The debris from that collision was thrown out into space, and that debris eventually joined together to form the Moon. The newly formed Moon traveled at just the right speed so that it remained within the control of Earth's gravitational field.

Now the Moon is Earth's natural satellite. This means that the Moon revolves around, or orbits, Earth. If the Moon were to travel too quickly, it could escape Earth's gravity and zoom out into space. If the Moon were to travel too slowly, Earth's gravity could overcome it and the Moon could fall to Earth.

Since the Moon is our nearest neighbor in the sky—about 384,000 kilometers away—it was the first object that humans visited when space travel became possible. Because the Moon has no atmosphere, it has no weather patterns. Because the Moon has no weather—no wind, rain, ice, or snow—it is still in its near-original state. This makes the Moon a perfect object for scientists to study the history and origin of the solar system.

The Moon is about 3500 kilometers in diameter. The Earth is 12,756 kilometers in diameter at the equator. (The Earth is not an exact sphere. It is slightly flattened at the poles, where its diameter is only 12,720 kilometers.)



One theory of how the Moon formed

This means that the Moon is slightly more than one-fourth (0.27) the size of Earth. See Table 1 for a summary of this information.

Natural Calendars

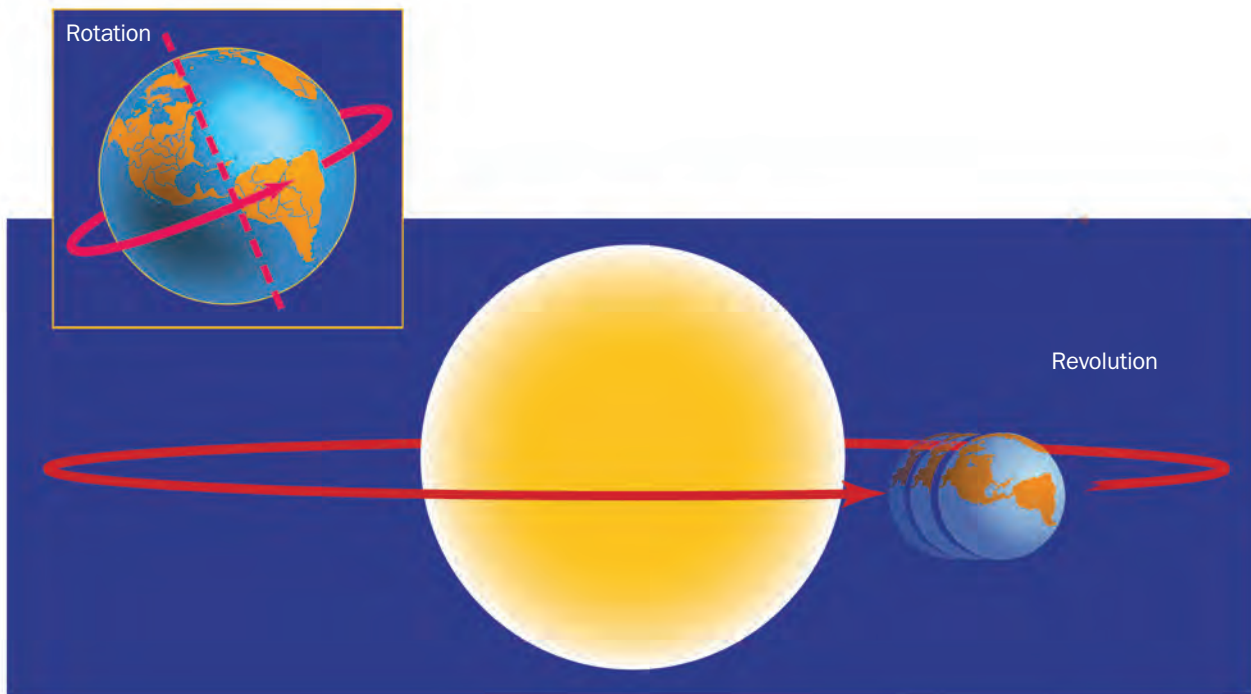
Earth rotates, or spins, on its axis. It also revolves, or orbits, around the Sun. Like Earth,

the Moon also rotates on its axis. But the Moon rotates much more slowly than Earth, taking approximately 27.3 days to turn once on its axis. The Moon also takes 27.3 days to orbit Earth.

The relative motions of the Sun, Earth, and Moon spurred ancient cultures to develop natural

Table 1 Size and Distance Comparison Sun-Earth-Moon Data

Solar System Body	Distance from Earth (km)	Earths Away	Diameter (km)	Earths Across
Sun	150,000,000	~12,000	1,392,000	109
Moon	384,000	30	3500	0.27
Earth			Equator = 12,756	1



Rotation and revolution

calendars and timekeeping methods that eventually led to the clocks, calendars, and timekeeping devices we use today.

Day and Night Day and night are caused by Earth's rotation on its axis. It takes Earth approximately 24 hours to rotate one time through day and night. This repetitive cycle of light and dark provides a clocklike regularity for measuring our days, and ancient cultures based the measure of a day on this rotation.

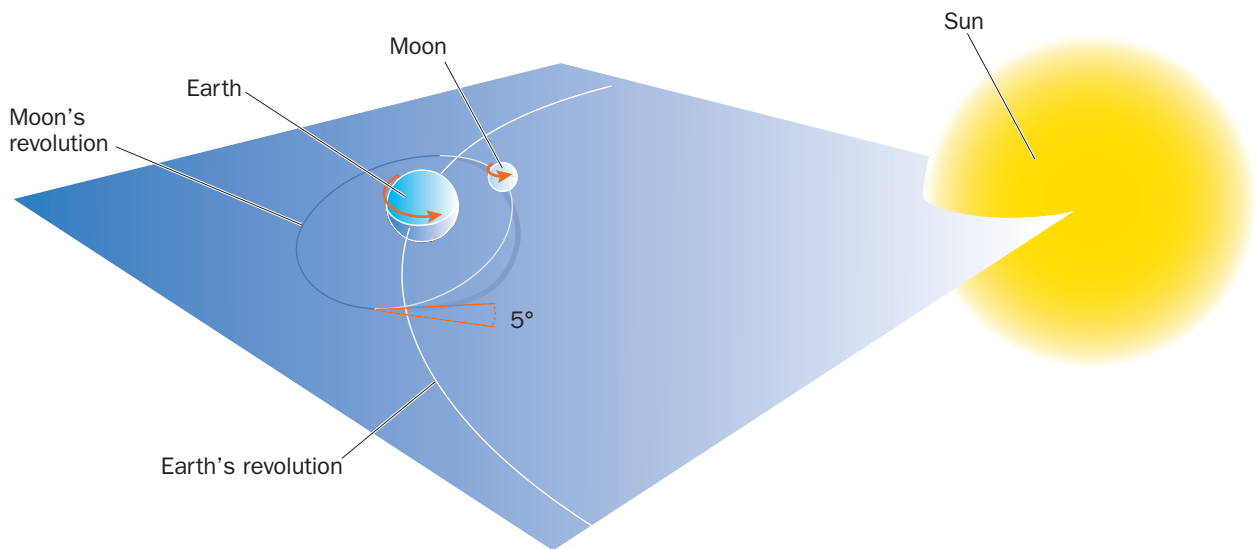
Month The Moon takes approximately one month—about 27 days—to orbit Earth. We observe the Moon's orbit by seeing its appearance change shape throughout each month. This repetitive cycle of the Moon's apparent change in shape led ancient cultures to identify this pattern and to measure each month.

Year It takes Earth $365\frac{1}{4}$ days, or one year, to orbit the Sun one time. Since a calendar year is 365 days long, we have an extra $\frac{1}{4}$ day every year that needs to be accounted for. So every four years, we have a leap year in which an extra day—February 29—is added to our calendar.

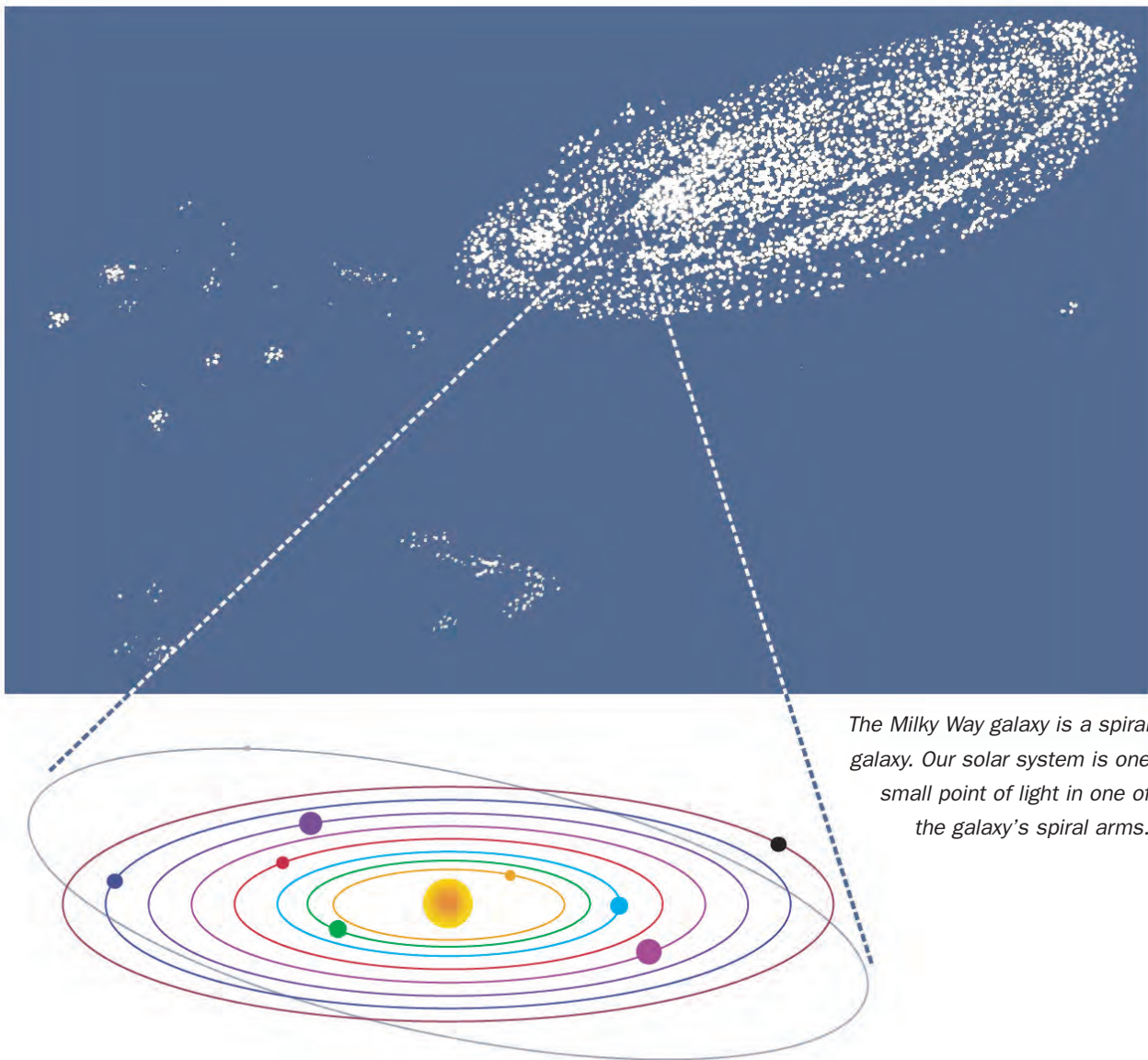
It's easy for us to see the links between the relative motions of the Sun, Earth, and Moon and the calendars and clocks that we use every day. But earlier civilizations had to carefully track these planetary motions to arrive at predictable, measurable results.

Our Sun the Star

Our Sun is the only star in our solar system. Within the Milky Way galaxy—the collection of dust, gas, and stars to which our solar system belongs—the Sun is just one of 100 billion or so stars. There are billions of other galaxies in the universe.



The geometry of the Sun-Earth-Moon system, showing the Moon and Earth's rotation and revolution



The Milky Way galaxy is a spiral galaxy. Our solar system is one small point of light in one of the galaxy's spiral arms.

The Sun may seem close to Earth, but it is actually about 150 million kilometers (93 million miles) away. With a diameter of 1,392,000 kilometers, the Sun is 400 times larger than the diameter of the Moon. The Sun is also 400 times farther away from Earth than the Moon is. This means that the Moon and Sun appear to be the same size in the sky.

The Sun is bigger in volume than anything we can imagine. One million Earths would fit inside the Sun, and 109 Earths could fit across the Sun's diameter.

Models of the Sun, Earth, and Moon

Sometimes the best way to understand abstract concepts is to use models. Models are smaller representations of an object that might be too large, too complex, or too far away to study firsthand. Look at the facts that you have read here. Use your models and what you know about math to demonstrate what you know about these facts. □