LESSON 5

Investigating Lunar Phases

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The waning crescent Moon shines down on the landscape as the Sun begins to rise.

INTRODUCTION

At certain times of the month, the Moon seems to rise over the horizon right before the Sun appears. When this apparent chase begins, the Moon usually looks like a sliver of light in the early morning sky. This "waning crescent," as it is called, is just one of many phases the Moon goes through as it journeys around Earth.

What causes the Moon's different phases, and what do these phases tell us about the Sun-Earth-Moon system? In this lesson, you will investigate how these three bodies interact to create lunar phases. You will model the phases of the Moon as it makes its way around Earth and examine the factors that affect these phase changes.

OBJECTIVES FOR THIS LESSON

Demonstrate that the Moon reflects the Sun's light as it orbits Earth.

Track, model, and illustrate the phases of the Moon as seen from Earth.

Create working definitions of the terms "waxing" and "waning."

Make predictions about the Moon's appearance on the basis of observed patterns.

Getting Started

1. Go over your homework from Lesson 2 with your class. Discuss any patterns that you observed in the Moon's rising and setting times and in its appearance.

2. Why do the rising and setting times and appearance of the Moon change over time? Share your ideas with the class.

3. Your teacher will set up a lamp in the center of your classroom. When do objects reflect light? When are objects in their own shadows? Test your ideas with your class.

MATERIALS FOR LESSON 5

For you

- 1 copy of Student Sheet 5.1: Investigating the Moon's Reflected Light
- 1 copy of Student Sheet 5.2: Modeling Phases of the Moon
- 1 copy of Student Sheet 5: Recording Lunar Phases Over Time

For your group

- 1 copy of Inquiry Master 5: Assessment: Identifying Lunar Phases
- 1 Sun-Earth-Moon Board™
- 1 set of 8 rods, labeled #1–#8
- 1 rod labeled "E"
- 1 globe of Earth, 12 cm
- 1 Mini Maglite®
- 2 AA batteries
- 1 large black-and-white sphere, 7.5 cm
- 1 white sphere, 3.5 cm
- 1 set of wide-tipped markers
- 1 sheet of newsprint
- 1 fine-point black marker
- 1 pair of scissors
- Glue
- 1 foam sleeve (optional)

Inquiry 5.1
Investigating the Moon's Reflected Light

PROCEDURE

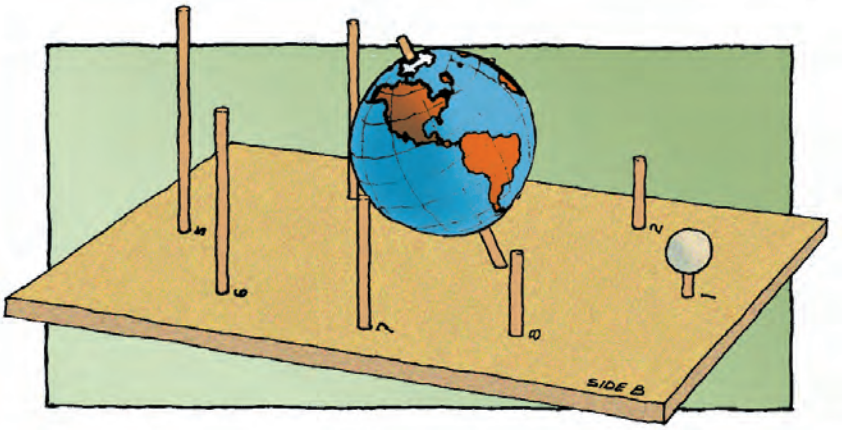


Figure 5.1 *Set up Side B of the Sun-Earth-Moon Board™ as shown. Push each rod into its corresponding hole. Attach the globe of Earth to the center rod labeled "E." Attach the 3.5-cm sphere to the rod labeled "1." (Note that this model is not to scale and that the tilt of the Moon's orbit is exaggerated for the purposes of the inquiry.)*

1. Look at one set of materials. How can you use the Sun-Earth-Moon (SEM) Board and a Mini Maglite to investigate how much of the Moon is illuminated by the Sun at any one time as the Moon orbits Earth? Discuss your ideas with your group. Then discuss the procedures of the inquiry with your teacher.

2. Set up Side B of your SEM Board as shown in Figure 5.1. Make sure that you match the number on each rod with the numbered holes on the board. Attach the globe of Earth to the center rod labeled "E." Each numbered rod represents a different position of the Moon along its orbit around Earth.

3. Push the smaller sphere onto rod #1 through the predrilled hole. If your sphere does not have a hole, make one with your pen tip. This sphere will represent the Moon in its orbit around Earth.

4. Reexamine the illustration in Figure 5.2, which is from Lesson 2. What do you notice about Earth, the Moon's orbital plane, and the Sun? Discuss your ideas with your group.

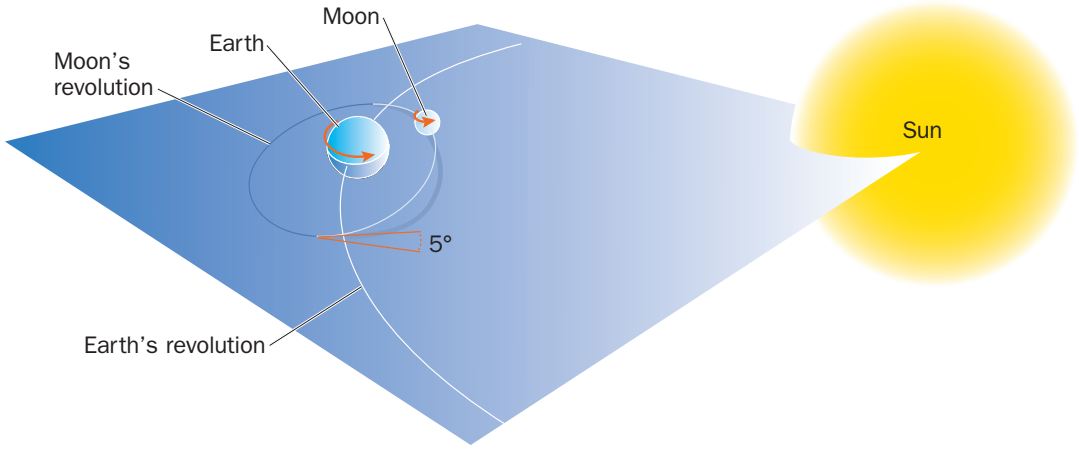


Figure 5.2 *Geometry of the Sun-Earth-Moon system showing the Moon's rotation and revolution (orbit). Note that the Moon's orbit is tilted approximately 5 degrees to Earth's orbital plane. This means that in most cases (except for two times each month), the Moon is either higher or lower than Earth, not level with it, as Earth orbits the Sun.*

5. Now compare Figure 5.2 to your SEM Board. What do you think the rods on your board represent? Why are the rods different heights? Why does the rod go through the globe at an angle? Discuss your ideas with your group.

6. Shine the Mini Maglite directly on the sphere on rod #1. Keep the Mini Maglite steady. Look at the sphere from all directions as if you are looking down at the Moon from space. How much of the sphere reflects light at any one time? Discuss your observations with your group. Color circle #1 on Student Sheet 5.1 to show how much of the Moon is dark and how much of it reflects light. Make sure that the student sheet is facing the same direction as your SEM Board.

7. Move the sphere to rod #2. Shine the Mini Maglite directly on your white sphere as you did with rod #1 (see Figure 5.3). Discuss your observations with your group. Record what you see in circle #2 on Student Sheet 5.1.

8. Repeat Step 7 with rods #3–#8. Record your observations on Student Sheet 5.1 each time.

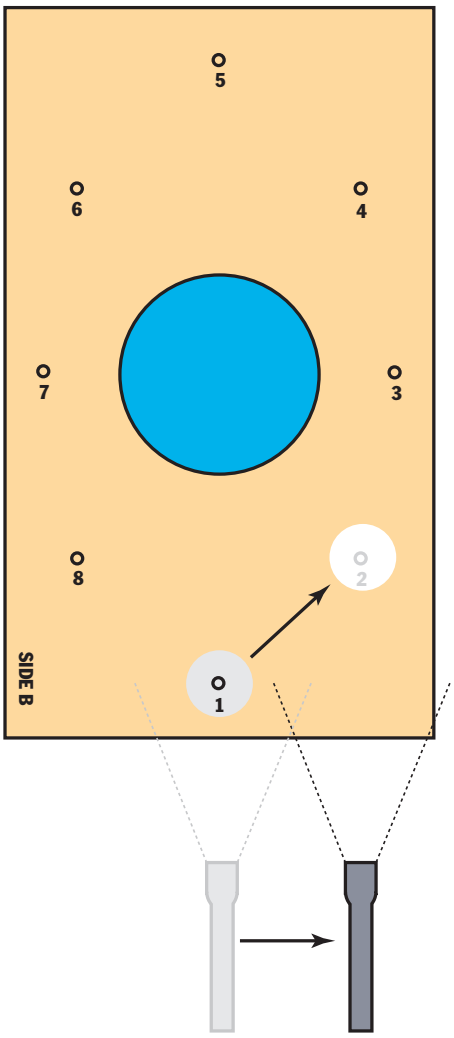


Figure 5.3 *Try to shine the light directly on the sphere each time you move the sphere.*

REFLECTING ON WHAT YOU'VE DONE

1. Answer the following questions in your science notebook, and then discuss them with your class:

A. As seen from space, how much of the Moon is illuminated by the Sun at each position as the Moon orbits Earth?

B. Given your results from Inquiry 5.1, why do you think the Moon appears to change its shape when viewed from Earth?

2. Draw a 360-degree circle that connects all eight of your completed Moons on Student Sheet 5.1. Then cut along that circle (see Figure 5.4).

3. Analyze the circle that you have cut out. What part of the Moon's lighted side can we see from Earth at each position in the Moon's orbit around Earth? On the back of your circle, write a paragraph summarizing your observations from this inquiry.

Figure 5.4 *Draw a circle to connect the eight Moons. Cut out the circle.*

Inquiry 5.2
Modeling Lunar Phases

PROCEDURE

1. Place the large black-and-white sphere on the end of a pencil. This will represent the Moon.

2. Face the cloth Sun. Hold the Moon out in front of you so that the white half of the Moon is facing the Sun, as shown in Figure 5.5. Your head represents Earth. What part of the Moon can you see from Earth?

3. Orbit the Moon around you. Stop at each of its 8 positions along its orbit. Remember to keep the white half of the Moon facing the cloth Sun at all times. How does the Moon look from Earth during each phase as it orbits Earth?

4. Record your observations on Student Sheet 5.2. Make sure that the Sun on your sheet is facing the same direction as the cloth Sun in your lab setup.

5. Switch roles within your group. Have another student hold the Moon, and repeat Steps 2–4. Do this until everyone has had a turn.

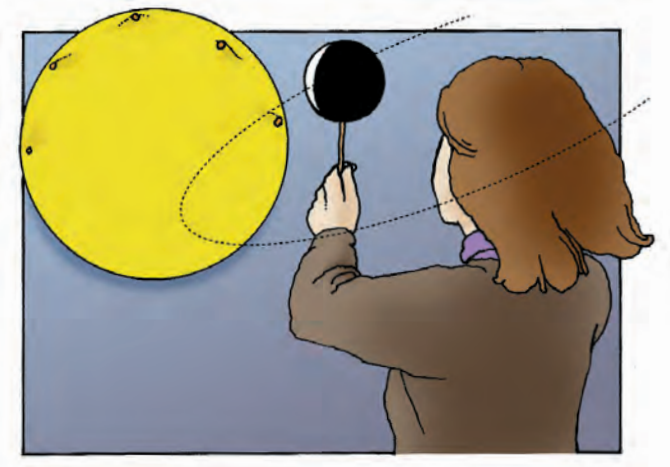


Figure 5.5 *If your head represents Earth, what part of the Moon's illuminated side can you see when the Moon is in this position?*

REFLECTING ON WHAT YOU'VE DONE

1. Share your results from Student Sheet 5.2 with the class.

2. Answer these questions in your science notebook, and then discuss them with the class:

   A. As seen from Earth, what causes the Moon to change its apparent shape throughout the month?

   B. Approximately how long does it take for the Moon to go through one set of phases? How many days does each phase last?

   C. Is the Moon visible only in the nighttime sky? Why or why not? (Think about what you saw when you were facing the Sun—which represents daytime on Earth.)

   D. Does everyone on Earth see the same phase of the Moon on any given day? Why or why not?

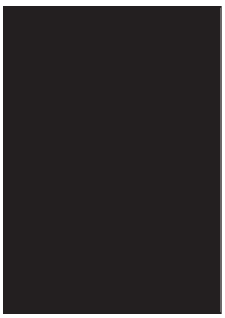
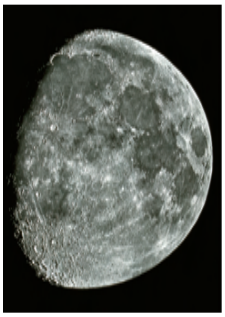
3. Is the same side of the Moon always dark? Discuss your ideas with the class.

4. Use Inquiry Master 5: Assessment: Identifying Lunar Phases to create a poster that shows the lunar phases in the correct order around Earth. Use Table 5.1: Lunar Phases to label each lunar phase on your poster.

5. Share your completed poster with the class. Create working definitions of the terms "waxing" and "waning."

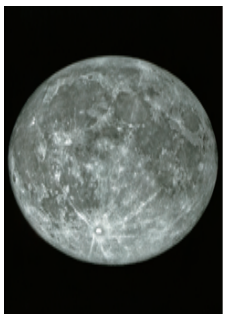
6. With your class, return to the Question C folder (from Lesson 1) and its accompanying photo card. Review the self-stick responses from Lesson 1 about why the Moon appears to change its shape. As a class, work together to remove any notes that now seem incorrect. Add any new ideas you have to the folder.

Table 5.1 Lunar Phases

Photo	Phase name	Description	Visibility, Location, and Time
	New Moon	Cannot be seen	
 COURTESY UCO/LICK OBSERVATORY	Waxing crescent	A narrow strip of the Moon's lighted hemisphere is visible from Earth. Shaped like a crescent. The light is on the right.	Visible late afternoon and just after sunset in the southwestern sky.
 COURTESY UCO/LICK OBSERVATORY	First quarter	Half of the lighted hemisphere is visible from Earth. Shaped like a semicircle. The light is on the right.	Visible afternoon and evening, until it sets about midnight.
 COURTESY UCO/LICK OBSERVATORY	Waxing gibbous	Three-quarters of the lighted hemisphere is visible from Earth. Shaped like an upended football. The light is on the right.	Visible in the eastern portion of the sky in the late afternoon. After sunset, the Moon moves across the southern part of the sky and sets sometime after midnight.

(continued)

Table 5.1 Lunar Phases (continued)

Photo	Phase name	Description	Visibility, Location, and Time
 COURTESY UCO/LICK OBSERVATORY	Full Moon	The Moon's entire lighted hemisphere is visible from Earth. Shaped like a full circle.	The full moon rises when the Sun sets, is up all night, and sets when the Sun rises.
 COURTESY UCO/LICK OBSERVATORY	Waning gibbous	Three-quarters of the Moon's lighted hemisphere is visible from Earth. Shaped like an upended football. The light is on the left. In this phase, the Moon wanes, or turns away from Earth.	Rises after sunset (as much as 5 or 6 hours later). Best seen in the southwest sky during the morning after sunrise.
 COURTESY UCO/LICK OBSERVATORY	Third (or last) quarter	Half of the Moon's lighted hemisphere is visible from Earth. Shaped like a semi-circle. The light is on the left.	Rises at midnight, sets at noon, much like the waning gibbous Moon.
 COURTESY UCO/LICK OBSERVATORY	Waning crescent	A narrow strip of the Moon's lighted hemisphere is visible from Earth. Shaped like a crescent. The light is on the left.	Can only be seen in the early morning.

Apollo 11 Lands On the Moon: A NASA Log

On July 20, 1969, a very famous day in American history, *Apollo 11* and two of its three crew members landed on the Moon. Michael Collins piloted the Command Module as it continued to orbit the Moon. Shortly thereafter, Neil Armstrong and Edwin (Buzz) Aldrin descended from the Lunar Module and explored the Moon's surface for more than two hours.

People from around the world watched the Moon landing on TV. The three crew members were instant heroes.

The following account traces some highlights of this famous journey, based primarily on a log from NASA.

July 16

Around 1100 Universal Time Coordinated (UTC), or 7 A.M. Eastern Daylight Time (EDT), the crew arrive at Launch Pad 39A at Kennedy Space Center in Florida. The weather is clear and calm—a good day for a liftoff. The Saturn V rocket, which will send the crew and spacecraft toward the Moon, is ready to go. It is 111 meters high and produces more than 3.4 million kilograms of thrust at liftoff. It is the largest, most powerful rocket ever flown.

The crew of three includes Mission Commander Neil Armstrong; Michael Collins, pilot of *Apollo;* and Edwin (Buzz) Aldrin, who will pilot *Eagle,* the Moon landing craft.

Hundreds of kilometers west at the Johnson Space Center in Houston, the staff of Mission Control prepare to monitor the space trip. Flight Director Clifford E. Charlesworth is in charge.

At 9:32 A.M. EDT, *Apollo* lifts off successfully.

By noon, *Apollo* is in the middle of its second orbit around Earth. The astronauts fire the engine that puts *Apollo* out of Earth's orbit and head toward the Moon. Its speed is around 39,000 kilometers per hour.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JOHNSON SPACE CENTER

The crew of Apollo 11 *(left to right): Commander Neil A. Armstrong, Command Module pilot Michael Collins, and Lunar Module pilot Edwin E. "Buzz" Aldrin*

July 19

After three days of travel, *Apollo 11* passes behind the Moon. It is out of radio contact with Mission Control for the first time. While the spacecraft is behind the Moon, the crew fires the thrust engine to slow the spacecraft enough that lunar gravity can capture it.

The crew sends photos of their landing site back to Earth. The site they have chosen is called *Mare Tranquillitas.* Although this name means the "Sea of Tranquility," it is not really a sea. It is a large, dark plain on the Moon's surface, called *maria*. It was chosen as a landing spot because it is flat and relatively free of large craters.

July 20

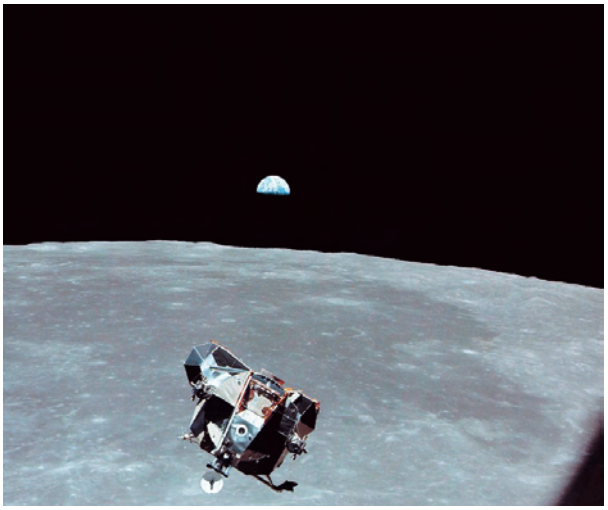
Astronauts Armstrong and Aldrin board the mooncraft *Eagle* to prepare it for landing. As they hover about 101 kilometers above the Moon's surface, the *Eagle* unlocks from the *Columbia.* Michael Collins, now alone in the *Columbia,* continues to orbit the Moon. Soon the *Eagle* begins its descent. Collins looks out his window at the *Eagle:* "I think you've got a fine-looking machine," he radios to his fellow crew members, "despite the fact you're upside-down."

When the *Eagle* is about 16 kilometers from the Moon, some computer alarms go off. The astronauts realize it's just a minor problem and will not affect the spacecraft. There is one problem, though: The *Eagle* overshoots its original landing site. Aldrin has to find a new place to land.

At 2018 UTC (or 4:18 P.M. EDT), with only 40 seconds of fuel remaining, the *Eagle* touches the surface of the Moon. Armstrong radios Mission Control with the long-awaited news: "The *Eagle* has landed." Aldrin describes the scenery as "magnificent desolation."

Aldrin and Armstrong spend a few hours preparing to leave the *Eagle* and explore the Moon. Their spacesuits are well padded to protect them from the jagged rocks and high-speed micrometeoroids that constantly bombard the Moon's surface. The suits weigh 83 kilograms on Earth. Because the Moon's gravity is much less than that of Earth, however, the suits feel as if they weigh only about 14 kilograms.

Armstrong, as commander, is the first to descend. He makes a footprint on the powdery soil. "That's one small step for a man, one giant leap for mankind," he radios to Earth.



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The mooncraft Eagle *hovers above the lunar surface as Earth shines in the background.*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

First footprint on the Moon left by Commander Neil Armstrong in the Sea of Tranquility. This footprint (barring any meteorite impacts) will probably last on the lunar surface for millions of years.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The astronauts plant a United States flag in the lunar soil.

Aldrin climbs down the *Eagle*'s ladder. "Now I want to back up and partially close the hatch—making sure not to lock it on my way out," he jokes.

The next two hours are busy ones. Aldrin sets up a solar wind experiment to catch particles from the Sun on a sheet of aluminum foil. He sets up a seismometer to record "moonquakes" and mirrors to reflect laser beams from Earth. These beams will enable astronomers on Earth to more precisely measure the distance between the Earth and Moon. Using tongs and a scoop, Armstrong collects rocks and soil samples.

The astronauts also plant a United States flag in the lunar soil. They take time for an important phone call—from President Richard Nixon. He tells them that he hopes that the mission will bring peace and tranquility to all of Earth.

About two hours and fifteen minutes after they first stepped on the Moon, the two men climb back into the *Eagle.* After a much-needed nap, they start the engine and begin their vertical ascent. Within a few hours, they redock with *Columbia.*

The astronauts abandon *Eagle,* which crashes into the Moon.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

On July 24, 1969, the Columbia *splashed down about 812 nautical miles southwest of Hawaii, returning the three crew members safely to Earth. Here they are shown in a life raft with a Navy frogman.*

July 24

After several days of testing and observation, the crew heads home. On July 24, 1969, at 1650 UTC (12:50 P.M. EDT), they splash down in the Pacific Ocean approximately 195 hours (eight days and three hours) after liftoff. They are retrieved by a helicopter and welcomed aboard the recovery ship, *USS Hornet*. □

QUESTIONS

1. When did the *Apollo 11* crew land on the Moon?
2. Where on the Moon did the *Eagle* land, and why was this spot selected?
3. What did Neil Armstrong say when he set foot on the Moon? What do you think he meant by this?
4. What experiments did the astronauts conduct while on the Moon? Why is it important to conduct experiments such as these?