Name _____ Date _____ Section_____

ACTIVITY 4

Studying the Phases of the Moon from a Privileged View

Learning Goals

Understanding the phases of the Moon requires visualizing the Earth-Moon-Sun system in three dimensions. In this activity, you will develop this ability by learning how to:

1. Successfully replicate the motions of the Earth and Moon, as well as their positions with respect to the Sun at each lunar phase.
2. Explain the continuity of the Moon phases worldwide.
3. Use an Earth-Moon figure to disprove a common misconception that Moon phases are caused by Earth's shadow.
4. Correctly order the phases of the Moon.

Step 1—Understanding the Rotation and Revolution

Take a full sheet of paper and crush it into a ball. This will represent Earth. Find something in your backpack to represent the Moon. The object should be about one-quarter the size of the crushed-paper Earth. If necessary, you can crush one-quarter of a sheet of paper to represent the Moon. Study the polar graph on the last page of this activity (see **Figure 4.5**). You want to make Earth rotate through 1 day while, at the same time, moving the Moon in its orbit the correct number of degrees each day. It will be easiest to do this if the models of Earth and the Moon are sitting on a guide. The Moon moves nearly 12° in its orbit every 24 hours (360° divided by a rounded-off 30 days in a month). For simplicity, consider all locations to mean those for viewers in the Northern Hemisphere—those who see the Moon located in the southern part of the sky as it crosses the meridian.

Place the polar graph sheet on the desk in front of you. Imagine the sunlight coming from the front of the classroom. Orient your paper so that the "Day 0 & 30" location on the graph is toward the "Sun." Set Earth on the center of the graph paper. Hold the Moon at "Day 0 & 30"—we will start with a new Moon, the same geometry as shown in **Figure 4.1**.

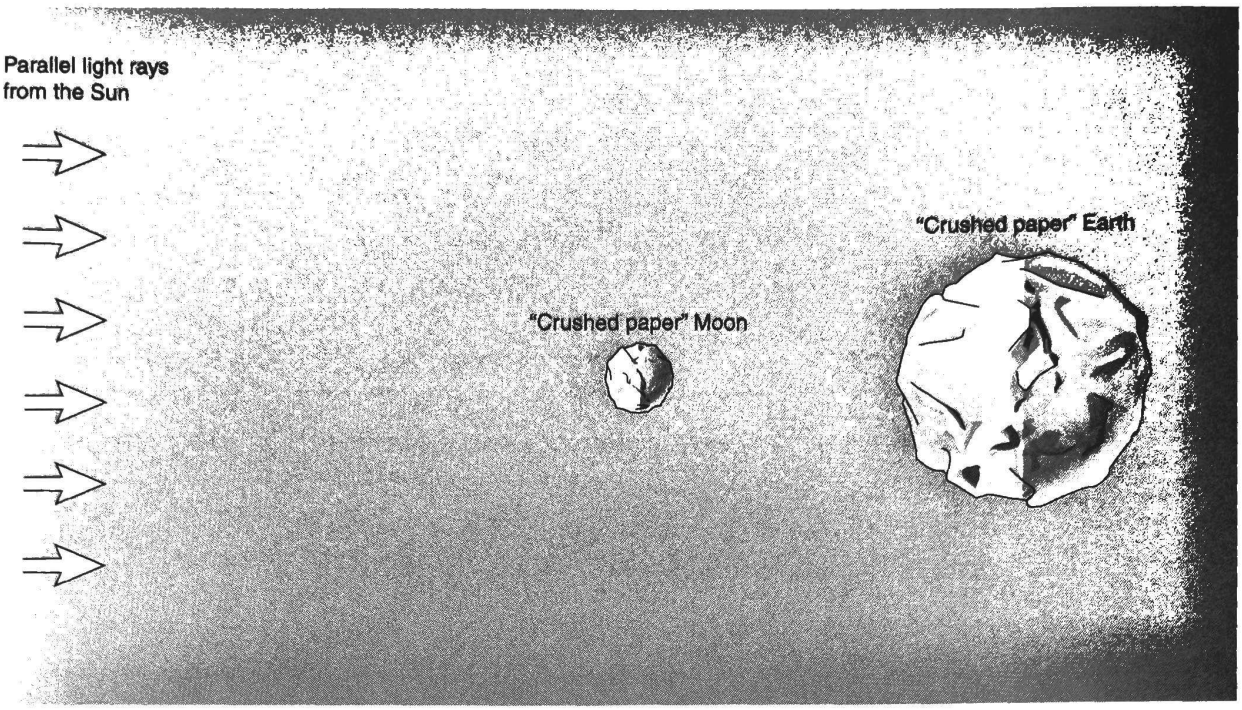


FIGURE 4.1

1. Starting with a new Moon, rotate the paper Earth once. If this is an accurate model, do all locations see approximately a new Moon (that is, if we could actually "see" a new Moon)? **Yes or No**
2. Each time Earth rotates, 1 day passes, and the Moon moves 12°. Move the Moon counterclockwise in its orbit, and again rotate Earth. Keep stepping through this process (rotate Earth once, move the Moon 12°) until you get to the first quarter Moon (7.5 rotations of Earth). Do all locations on Earth see a first quarter Moon, or very close to this phase, over the course of one rotation of Earth? **Yes or No**
3. Move the Moon and rotate Earth until the alignment is Sun-Earth-Moon (Moon on the "Day 15" mark). What is the phase of the Moon when the system is in this configuration?

   _____
4. Do all locations on Earth see this phase, or very close to this phase, over the course of one rotation of Earth? **Yes or No**
5. Continue another 7.5 days. What is the phase of the Moon? _____
6. Briefly summarize your answers for questions 1–4, explaining what phases of the Moon are observed at different locations on Earth over just one complete rotation.

Step 2—Phases and Earth's Shadow

A common misconception is that the phases of the Moon are caused by Earth's shadow. **Figure 4.2** depicts the orbit of the Moon around Earth. The Sun is far off the paper to the left. If Earth's diameter in this image were 2.5 cm, Moon's orbit would have a radius of 75 cm, and the Sun would be more than three football fields away.

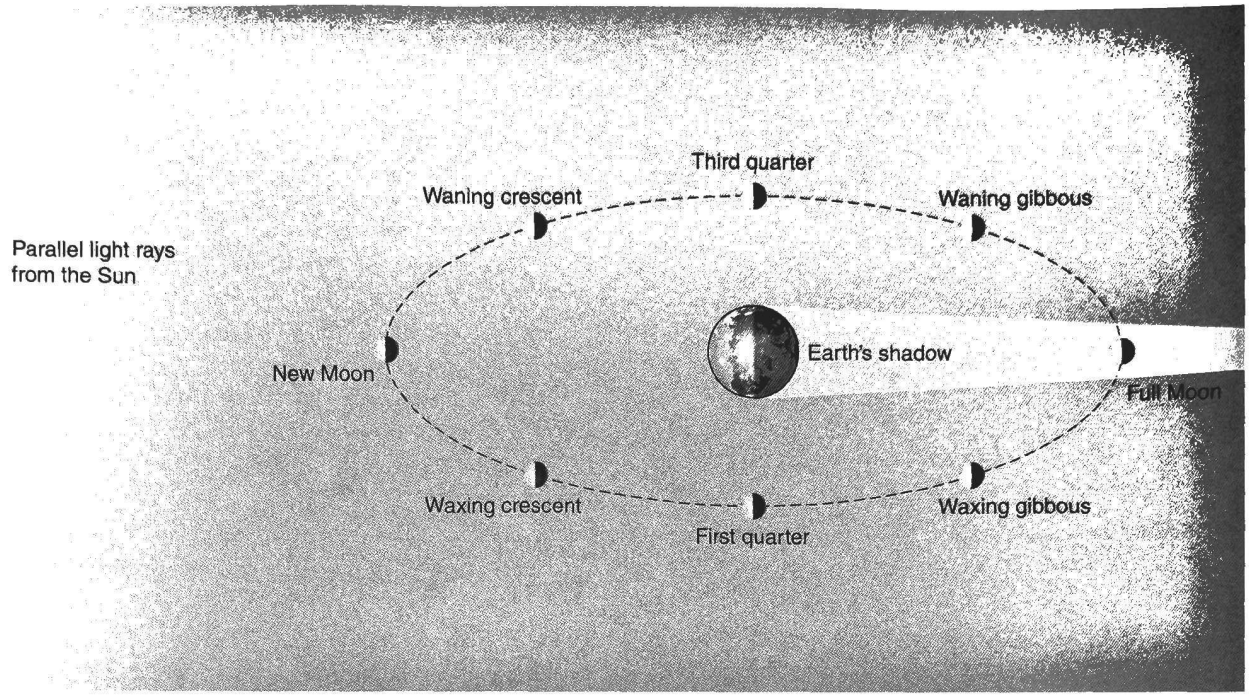
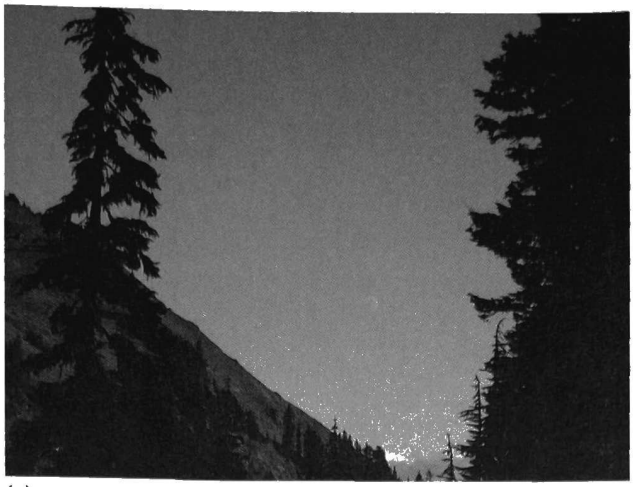


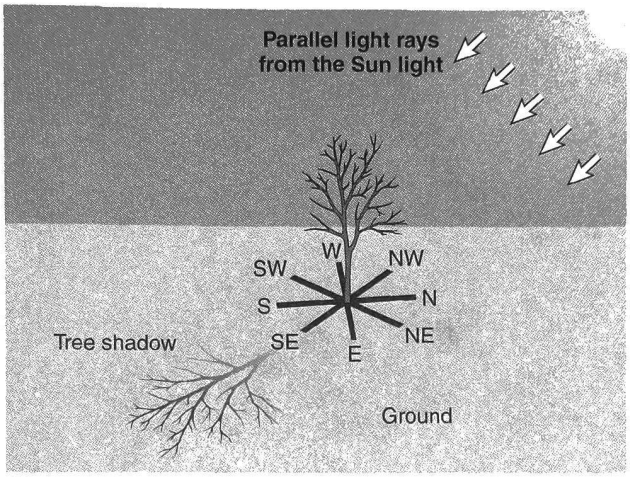
FIGURE 4.2

7. Earth's shadow is shown on Figure 4.2 as it would look when the Moon was full. If the phases of the Moon were caused by the Earth's shadow falling on it, would we ever see a full Moon? Explain your answer, bringing in why the inclination of the orbit of the Moon would matter.

8. Keeping the Earth's shadow in the direction and shape shown, could you show how any of the other phases could be caused by the shadow of Earth? How or why not?



(a)



(b)

FIGURE 4.3

Just one actual observation is needed that negates this "shadowed Moon" idea in order to disprove the hypothesis. **Figure 4.3a** shows an observation that does just that. The phase is first quarter and the Sun is still up, located in the NW. The Moon is in the SW sky. Remember that the Moon is very far away, and the Sun is almost 400 times farther away than the Moon.

9. Shadows always point in the opposite direction from the Sun. Because the Sun is in the NW in Figure 4.3a, the shadows of the trees in Figure 4.3b must point toward the _____ direction.

10. The shadow of the Moon must point to the _____ direction.

11. The shadow of Earth must point toward its_____ direction

12. State how this observation disproves the "shadowed Moon" hypothesis.

Step 3—Understanding the Order of Moon Phases

Figure 4.4 shows the phases of the Moon in random order. Starting with "K" (a new Moon), put the phases in order, from new Moon to full Moon and back to new again.

k											k

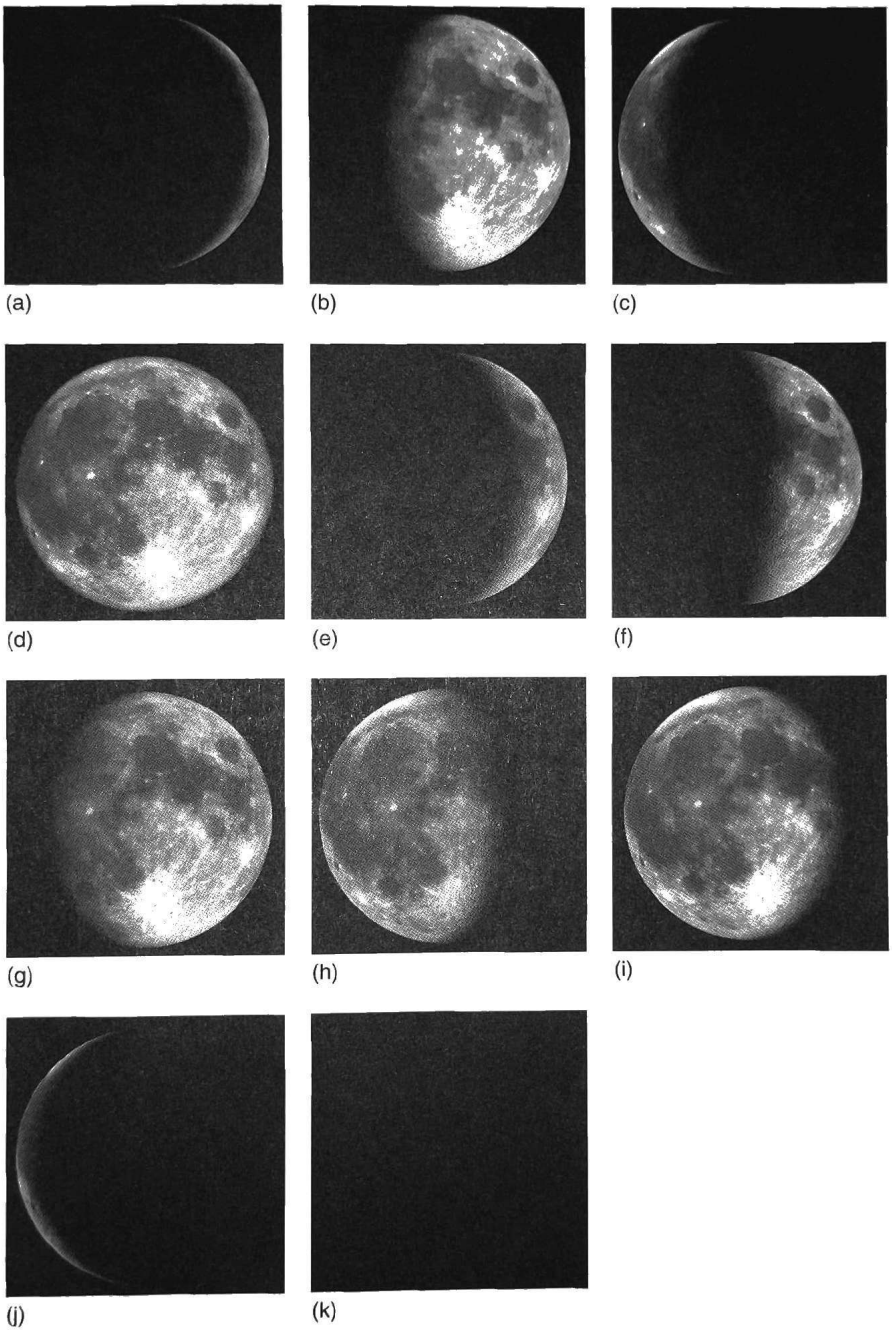


FIGURE 4.4

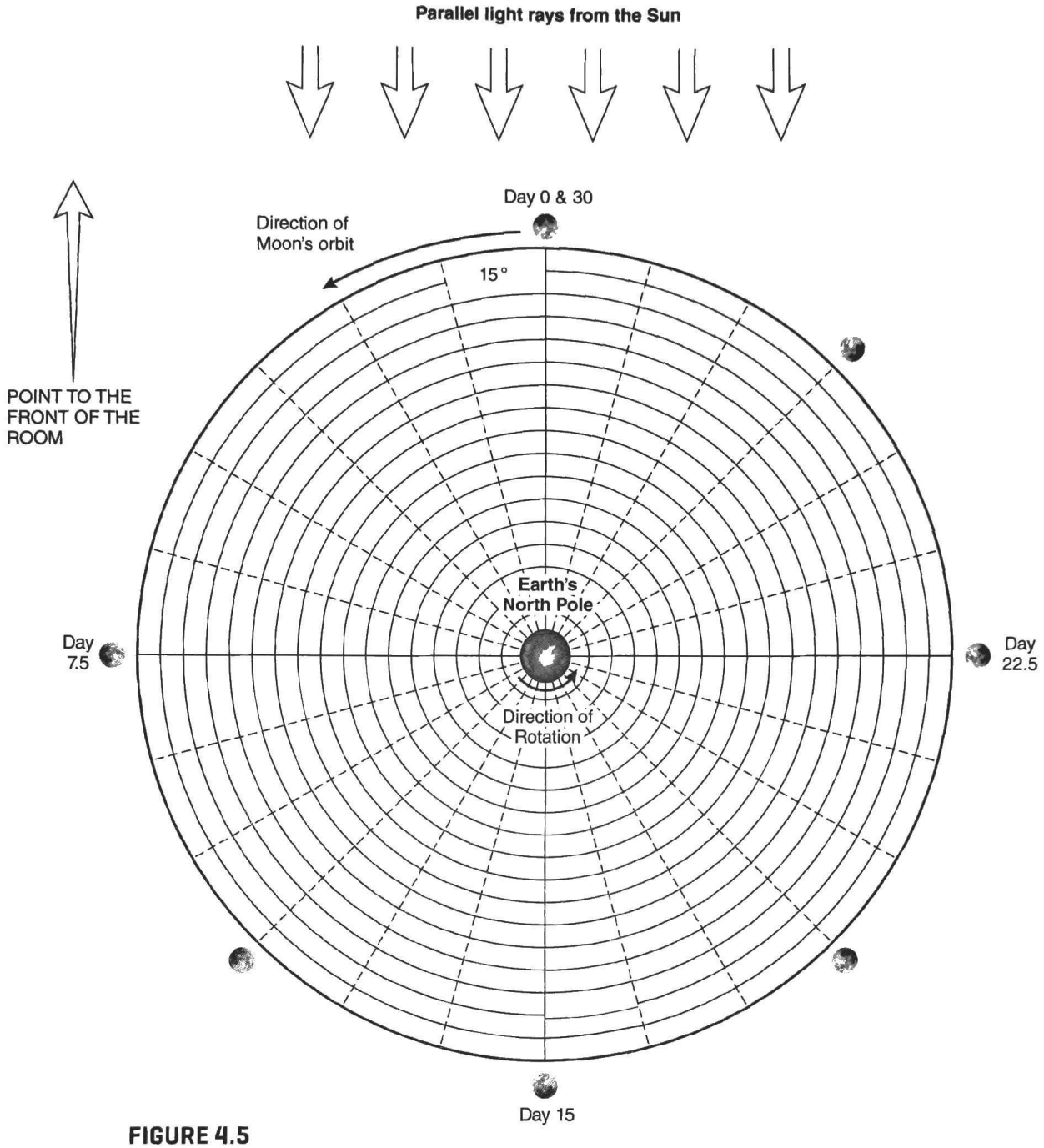

Parallel light rays from the Sun
POINT TO THE FRONT OF THE ROOM
Day 0 & 30
Direction of Moon's orbit
15°
Earth's North Pole
Direction of Rotation
Day 7.5
Day 22.5
Day 15

FIGURE 4.5