

## Lunar Phase Simulator

The changing appearance of the moon is the most commonly observed astronomical phenomenon. The moon's cycle of phases has importance in almost all cultures, and even today we use periods of time — the week and month — which likely have their origin in lunar cycles.

A common assumption is that the earth's shadow falling on the moon causes its phases. In fact, the dark part of the moon is the half of the moon that is on the opposite side from the sun — the nighttime half of the moon. While half of the moon is always in darkness, keep in mind that there is no permanent 'dark side' since the moon rotates.

However, since the moon rotates at the same rate it orbits around the earth it always keeps the same side toward us. In the pictures below features stay in the same relative place. The other side of the moon, the far side, cannot be seen from earth.



Waxing Crescent      First Quarter      Waxing Gibbous      Full      Waning Gibbous      Third Quarter      Waning Crescent

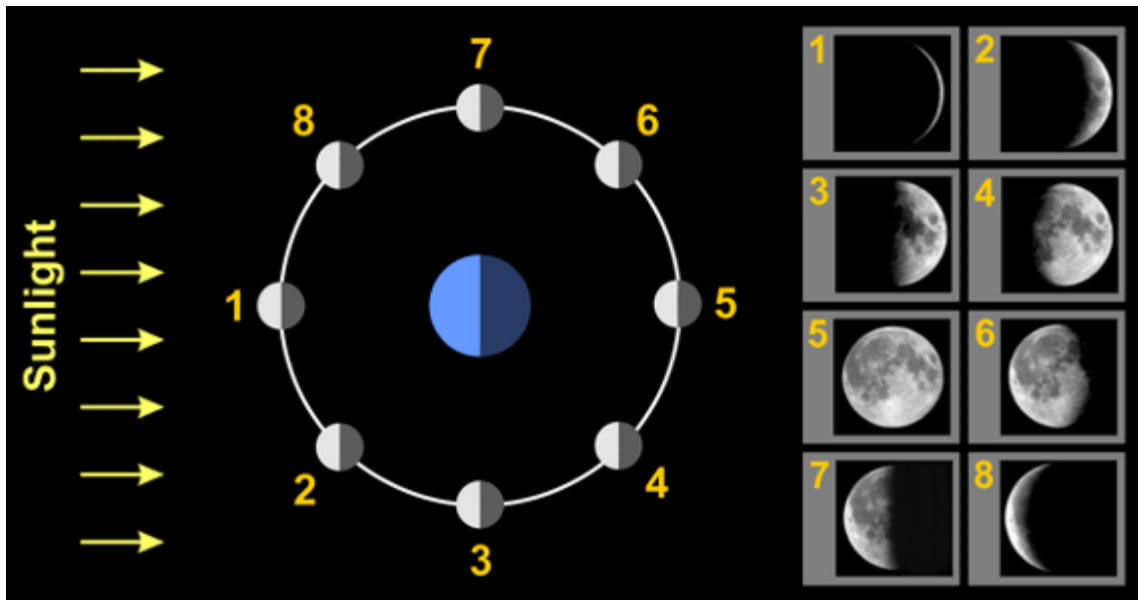
The sequence of images above shows the phases of the moon in their relative order. During the first half of the cycle (new to full) the moon is illuminated on the right hand side, and during the second half of the cycle (full back to new) it is illuminated on the left hand side. Another way to remember this is the following: “When the light is on the right, it will soon be bright.”

To describe how much of the moon appears illuminated we can calculate the **percent illuminated**, or the fraction of the moon's surface that is lit as seen from earth. A **new moon** is 0% illuminated (completely dark) and a **full moon** is 100% illuminated (fully lit). Both **first quarter** and **third quarter** occur when the moon is 50% illuminated.

When the percent illumination is increasing we say that the moon is **waxing**, and when the percent illumination is decreasing we say that the moon is **waning**. When the moon is more than 50% illuminated it is **gibbous**, and when it is less than 50% illuminated it is a **crescent**.

The fraction of the moon that appears illuminated changes since the moon is orbiting the earth. The time it takes the moon to complete one orbit around the earth (with respect to the sun) is also the amount of time it takes to complete one cycle of phases. This period, known as the **synodic month, is about 29.5 days**. It follows that in one week the moon completes about a quarter of its orbit. So if the moon is at first quarter today, then in one week it should be near full.

The diagram below shows the relationship between the position of the moon in its orbit and its appearance from earth. Here we are looking down from far above the earth's North Pole. From this direction, the moon orbits the earth in a counter-clockwise direction.

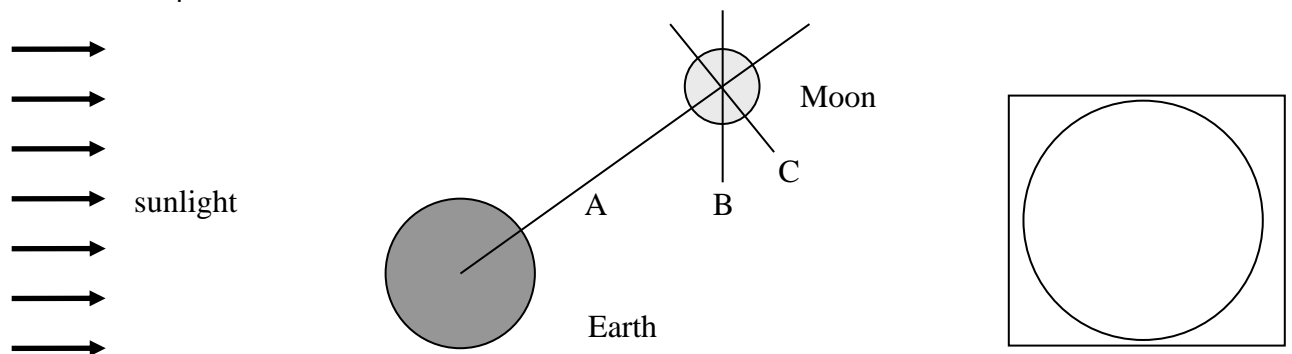


Phase	Phase
1	5
2	6
3	7
4	8

### Visualizing Phases

A simple illustration can be used to determine the appearance of the moon based on the orientation of the moon. Using the figure below you will bisect the moon *twice*.

- Line B has been drawn perpendicular to the direction of sunlight that shows the half of the entire moon that is illuminated. **Shade in the shadowed region of the moon.**
- Line C has been drawn perpendicular to the Earth-moon line (A) that shows the half of the moon visible for an observer on earth.
- Mark the region that is both visible from earth and illuminated by the sun.** That region will be the phase of the moon we on earth see.

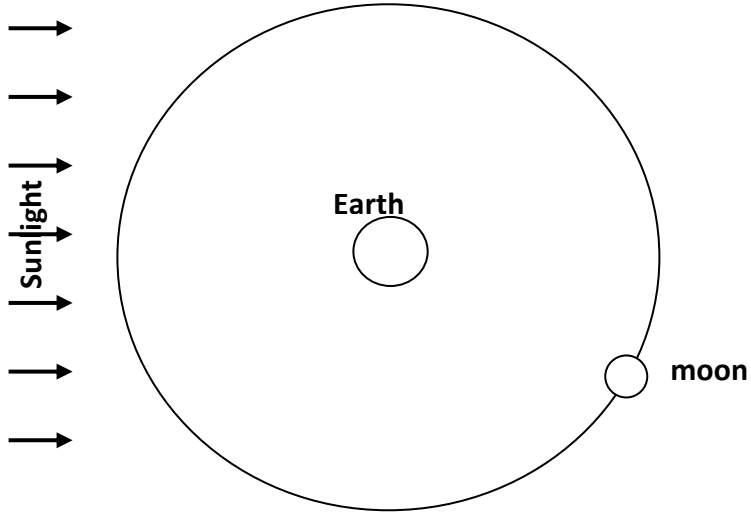


The phases of the moon are drawn with the terminator (the dividing line between light and shadow) from the north pole to the south pole of the moon. **Use the drawing above to draw the appearance of the moon in the box to the right.**

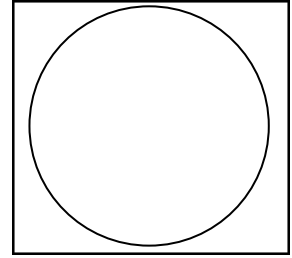
- Open the Moon Bisector Demo and use the simulator to check your answer.**

Use the simulation to sketch the shadows for Sun-Earth-Moon Geometry shown below and then sketch the appearance of the moon as seen from the earth.

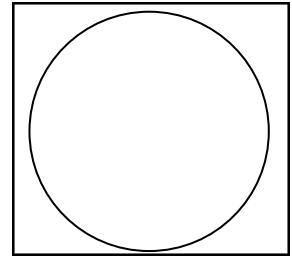
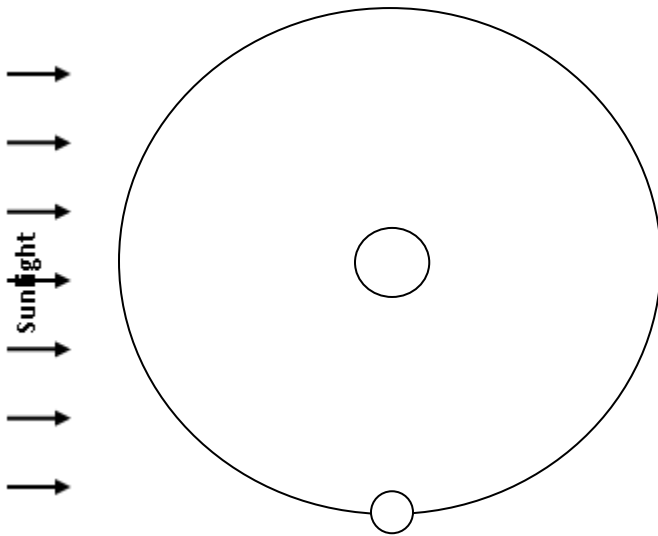
### Sun-Earth-Moon Geometry



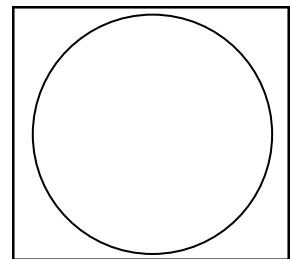
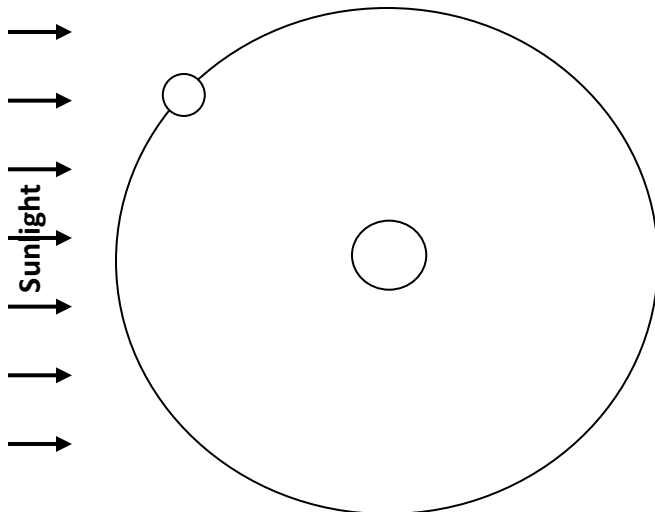
### Moon's Appearance



Phase \_\_\_\_\_



Phase \_\_\_\_\_



Phase \_\_\_\_\_

## Working with the Lunar Phase Simulator

The items below will help familiarize yourself with the controls and usability features of the simulator.

- Launch the **Lunar Phase Simulator**
- The main panel has sunlight, the earth, and moon. The earth and moon can be dragged with the mouse.
- Below the main panel, there are animation controls. The moon and earth can be dragged.
- The **Moon Phase** panel shows the current moon phase. Drop down menus will jump to a predefined position.
- The **Horizon Diagram** panel displays the point of view of the observer (and you are a second observer looking down on that observer).
- The observer's horizon diagram can be dragged to allow for the most convenient viewing orientation.
- The sun and moon on the globe can be dragged around.
- In the **Diagram Options** panel, the **show angle** option shows the earth-moon-sun angle. The phases are technically defined in terms of this angle.
- In the **Diagram Options** panel, the **show time tickmarks** option displays the time of day of the observer.

### PART I: EARTH – MOON – SUN GEOMETRY

Click on the option labeled show angle – which graphically displays the angle between the direction of the sun and moon. Now drag the moon around the sun to a variety of different locations and note the appearance of the Moon Phase.

- Describe how the value of the angle correlates with the appearance of the moon.
- Complete the table below.

Sun-Earth-Moon Angle	Phase	Time Since New Moon	% Illuminated	Side Illuminated (Right / Left)
0°	New Moon	0 days 0 hours	0%	----
45°				
90°				
135°				
180°				-----
135°				
90°				
45°				

**PART II: RISING, SETTING, AND MERIDIAN TIMES**

When observing the moon one thing we might like to know in advance is when it is visible – what time it sets, rises, and crosses the meridian (due south at it’s greatest altitude above the horizon.)

**Question: At what time of day can the moon be found due south during a new moon?**

Using the Horizon Diagram, move the moon to the new moon position. Rotate the earth until the moon is centered on the meridian (due south). You may need to play with the orientation to get a better view of the positions. Note that the transit time of the new moon is 12:00 PM (noon).

**Question: What is the setting time for a full moon?**

With the moon at the full position, rotate the earth while keeping an eye on the horizon diagram in the lower right corner. Rotate the earth until the moon just disappears below the western horizon. You should verify that this occurs at 6:00 AM.

- Complete the rest of the rising and setting times in the table above.

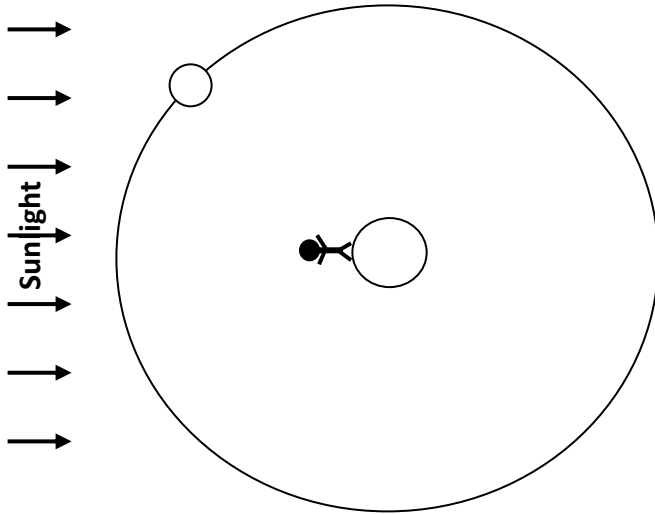
Phase	Rising	Meridian Crossing	Setting
New		12:00 PM	
Waxing Crescent			
First Quarter			
Waxing Gibbous			
Full			6:00 AM
Waning Gibbous			
Third Quarter			
Waning Crescent			

- During the waxing phases of the cycle, which rises first, the sun or the moon?
- Which side of the moon (right or left) is illuminated during the waxing phases?
- During the waning phases of the cycle, which rises first, the sun or moon?
- Which side of the moon (right or left) is illuminated during the waning phases?

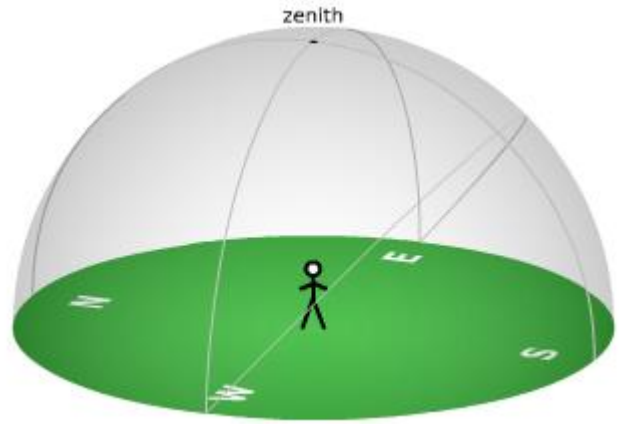
**PUTTING IT TOGETHER**

On the following page are three examples of analyzing the positions of the observer, sun and moon. Using the Sun-Earth-Moon geometry and the orientation of the observer to the sun, you will plot the positions of the moon and sun on the diagram to the right and complete the table for each situation.

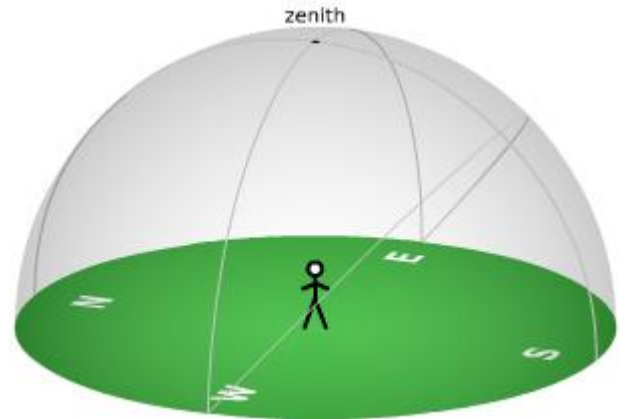
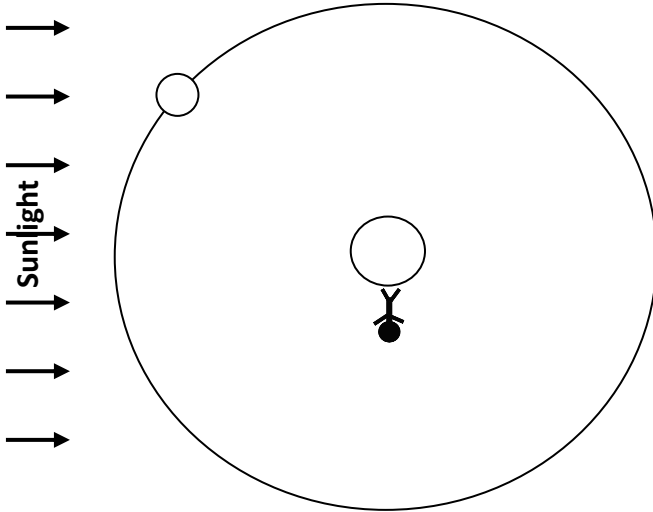
### Sun-Earth-Moon Geometry



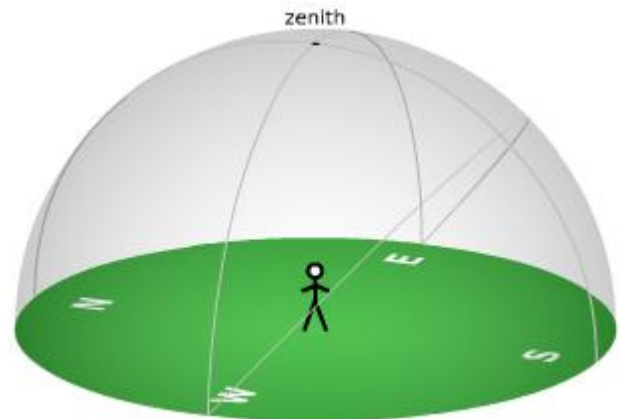
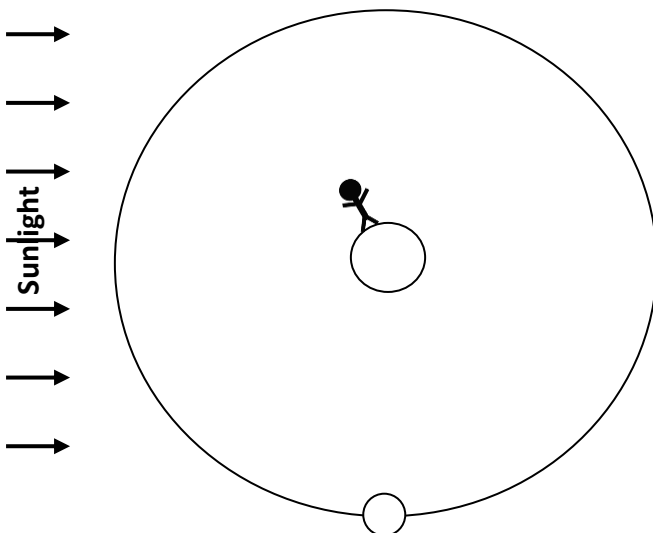
### Sun - Moon Positions



Time of Day	Phase	Sun-Earth-Moon Angle
Azimuth of Sun	Azimuth of Moon	% Illumination



Time of Day	Phase	Sun-Earth-Moon Angle
Azimuth of Sun	Azimuth of Moon	% Illumination



Time of Day	Phase	Sun-Earth-Moon Angle
Azimuth of Sun	Azimuth of Moon	% Illumination

**Problem Set: Lunar Cycle**

Name \_\_\_\_\_

1. What is meant by the term “waxing”? What is meant by the term “waning”?
2. When the moon is waning, is it located to the right or to the left of the sun in the sky?
3. Which will set first, the sun or the moon when the moon is waxing? Which will rise first when waxing?
4. Which will set first, the sun or the moon when the moon is waning? Which will rise first when waning?
5. It’s a full moon . If I see the sun setting in the west where will I find the moon? Explain your reasoning.
6. The angle formed by the **first quarter** moon and the sun is  $90^\circ$ . If the sun is setting, would I be able to see the moon? Where in the sky would I look to see the moon?
7. What phases of the moon can be observed only during the day (while the sun is above the horizon)?
8. What phases of the moon can be observed only during the evening (while the sun is below the horizon)?
9. We see only one side of the moon. Does the moon rotate on its axis? If it takes 29 days for the moon to complete one lunar cycle, how long does it take the moon to rotate one about its axis?
10. Watch the YouTube video on the eclipses. What is the orientation of the sun-earth-moon for a solar eclipse to occur? What phase must the moon be in to have a solar eclipse?
11. What is the orientation of the sun-earth-moon for a lunar eclipse to occur? What phase must the moon be in to have a lunar eclipse?
12. Why are solar and lunar eclipses so rare? Why don’t eclipses occur twice a month?