

Name(s): \_\_\_\_\_  
Date: \_\_\_\_\_

## 3 Phases of the Moon

### 3.1 Introduction

Every once in a while, your teacher or TA is confronted by a student with the question “Why can I see the Moon today, is something wrong?”. Surprisingly, many students have never noticed that the Moon is visible in the daytime. The reason they are surprised is that it confronts their notion that the shadow of the Earth is the cause of the phases—it is obvious to them that the Earth cannot be causing the shadow if the Moon, Sun and Earth are simultaneously in view! Maybe you have a similar idea. You are not alone, surveys of science knowledge show that the idea that the shadow of the Earth causes lunar phases is one of the most common misconceptions among the general public. Today, you will learn why the Moon has phases, the names of these phases, and the time of day when these phases are visible.

Even though they adhered to a “geocentric” (Earth-centered) view of the Universe, it may surprise you to learn that the ancient Greeks completely understood why the Moon has phases. In fact, they noticed during lunar eclipses (when the Moon *does* pass through the Earth’s shadow) that the shadow was curved, and that the Earth, like the Moon, must be spherical. The notion that Columbus feared he would fall off the edge of the flat Earth is pure fantasy—it was not a flat Earth that was the issue of the time, *but how big the Earth actually was* that made Columbus’ voyage uncertain.

The phases of the Moon are cyclic, in that they repeat every month. In fact the word “month”, is actually an Old English word for the Moon. That the average month has 30 days is directly related to the fact that the Moon’s phases recur on a 29.5 day cycle. Note that it only takes the Moon 27.3 days to orbit once around the Earth, but the changing phases of the Moon are due to the relative positions of the Sun, Earth, and Moon. Given that the Earth is moving around the Sun, it takes a few days longer for the Moon to get to the same *relative* position each cycle.

Your textbook probably has a figure showing the changing phases exhibited by the Moon each month. Generally, we start our discussion of the changing phases of the Moon at “New Moon”. During New Moon, the Moon is invisible because it is in the same direction as the Sun, and cannot be seen. Note: because the orbit of the Moon is tilted with respect to the Earth’s orbit, the Moon rarely crosses in front of the Sun during New Moon. When it does, however, a spectacular “solar eclipse” occurs.

As the Moon continues in its orbit, it becomes visible in the western sky after sunset a few days after New Moon. At this time it is a thin “crescent”. With each passing day, the crescent becomes thicker, and thicker, and is termed a “waxing” crescent. About seven days

after New Moon, we reach “First Quarter”, a phase when we see a half moon. The visible, illuminated portion of the Moon continues to grow (“wax”) until fourteen days after New Moon when we reach “Full Moon”. At Full Moon, the entire, visible surface of the Moon is illuminated, and we see a full circle. After Full Moon, the illuminated portion of the Moon declines with each passing day so that at three weeks after New Moon we again see a half Moon which is termed “Third” or “Last” Quarter. As the illuminated area of the Moon is getting smaller each day, we refer to this half of the Moon’s monthly cycle as the “waning” portion. Eventually, the Moon becomes a waning crescent, heading back towards New Moon to begin the cycle anew. Between the times of First Quarter and Full Moon, and between Full Moon and Third Quarter, we sometimes refer to the Moon as being in a “gibbous” phase. Gibbous means “hump-backed”. When the phase is increasing towards Full Moon, we have a “waxing gibbous” Moon, and when it is decreasing, the “waning gibbous” phases.

The objective of this lab is to improve your understanding of the Moon phases [a topic that you WILL see on future exams!]. This concept, the phases of the Moon, involves

1. the position of the Moon in its orbit around the Earth,
2. the illuminated portion of the Moon that is visible from here in Las Cruces, and
3. the time of day that a given Moon phase is at the highest point in the sky as seen from Las Cruces.

You will **finish** this lab by demonstrating to your instructor that you do clearly understand the concept of Moon phases, including an understanding of:

- which direction the Moon travels around the Earth
- how the Moon phases progress from day-to-day
- at what time of the day the Moon is highest in the sky at each phase

## Materials

- small spheres (representing the Moon), with two different colored hemispheres. The **dark** hemisphere represents the portion of the Moon not illuminated by the Sun.
- flashlight (representing the Sun)
- yourself (representing the Earth, and your nose Las Cruces!)

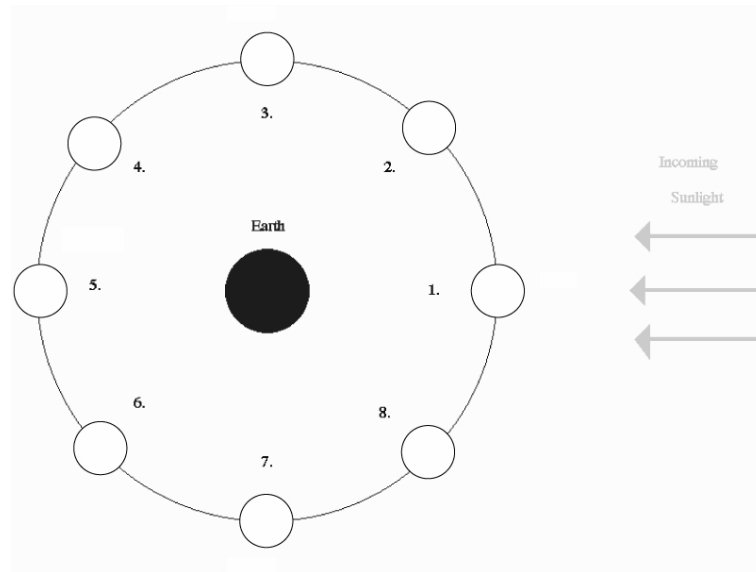
You will use the colored sphere and flashlight as props for this demonstration. Carefully read and thoroughly answer the questions associated with each of the five Exercises on the following pages. [Don’t be concerned about eclipses as you answer the questions in these Exercises]. Using the dual-colored sphere to represent the Moon, the flashlight to represent the Sun, and a member of the group to represent the Earth (with that person’s nose representing Las Cruces’ location), ‘walk through’ and ‘rotate through’ the positions indicated in the Exercise figures to fully understand the situation presented.

Note that there are additional questions at the end.

## Work in Groups of Three People!

### 3.2 Exercise 1 (10 pts)

The figure below shows a “top view” of the Sun, Earth, and eight different positions (1-8) of the Moon during one orbit around the Earth. Note that the distances shown are **not** drawn to scale.



**Ranking Instructions:** Rank (from *greatest* to *least*) the amount of the Moon’s **entire surface** that is illuminated for the eight positions (1-8) shown.

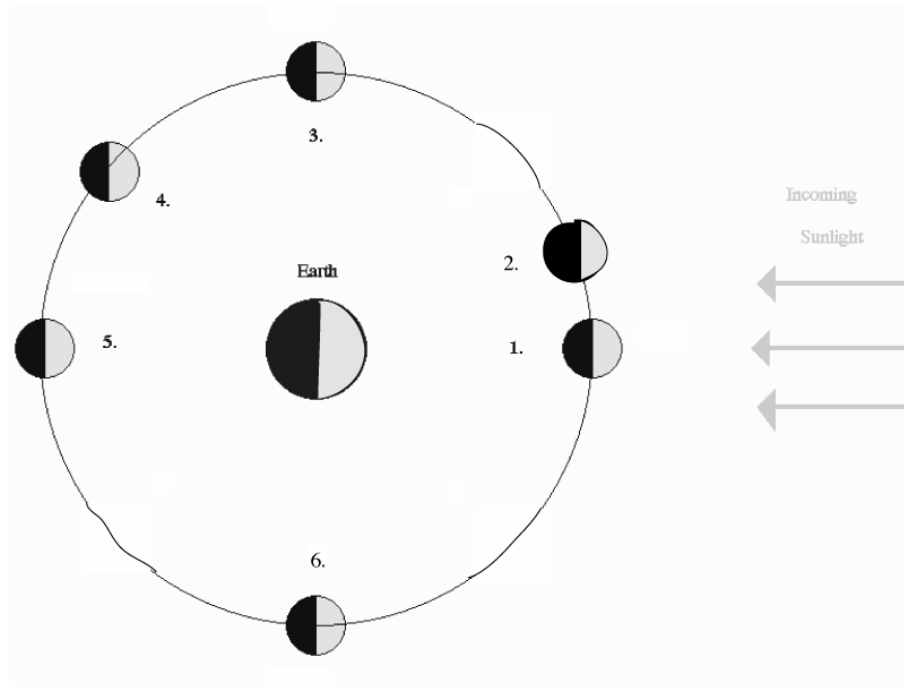
**Ranking Order:** Greatest A \_\_\_\_ B \_\_\_\_ C \_\_\_\_ D \_\_\_\_ E \_\_\_\_ F \_\_\_\_ G \_\_\_\_ H \_\_\_\_ Least

Or, the amount of the entire surface of the Moon illuminated by sunlight is the same at all the positions. \_\_\_\_\_ (indicate with a check mark).

**Carefully explain** the reasoning for your result:

### 3.3 Exercise 2 (10 pts)

The figure below shows a “top view” of the Sun, Earth, and six different positions (1-6) of the Moon during one orbit of the Earth. Note that the distances shown are **not** drawn to scale.



**Ranking Instructions:** Rank (from *greatest* to *least*) the amount of the Moon’s illuminated surface that is **visible from Earth** for the six positions (1-6) shown.

**Ranking Order:** Greatest A \_\_\_\_\_ B \_\_\_\_\_ C \_\_\_\_\_ D \_\_\_\_\_ E \_\_\_\_\_ F \_\_\_\_\_ Least

Or, the amount of the Moon’s illuminated surface visible from Earth is the same at all the positions. \_\_\_\_\_ (indicate with a check mark).

**Carefully explain** the reasoning for your result:

### 3.4 Exercise 3 (10 pts)

Shown below are different phases of the Moon as seen by an observer in the Northern Hemisphere.



A

B

C

D

E

**Ranking Instructions:** Beginning with the *waxing gibbous* phase of the Moon, rank all five Moon phases shown above in the order that the observer would see them over the next four weeks.

**Ranking Order:**

1) Waxing Gibbous

2) \_\_\_\_\_

3) \_\_\_\_\_

4) \_\_\_\_\_

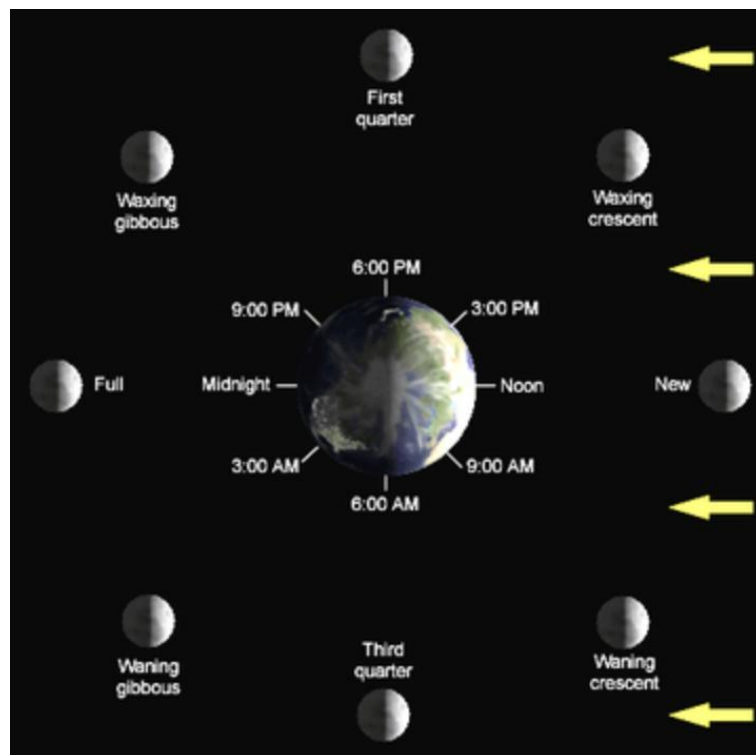
5) \_\_\_\_\_

Or, all of these phases would be visible at the same time: \_\_\_\_\_ (indicate with a check mark).

## 4 Lunar Phases, and When They Are Observable







The next three exercises involve determining when certain lunar phases can be observed. Or, alternatively, determining the approximate time of day or night using the position and phase of the Moon in the sky.

In Exercises 1 and 2, you learned about the changing geometry of the Earth-Moon-Sun system that is the cause of the phases of the Moon. When the Moon is in the same direction as the Sun, we call that phase New Moon. During New Moon, the Moon rises with the Sun, and sets with the Sun. So if the Moon's phase was New, and the Sun rose at 7 am, the Moon also rose at 7 am—even though you cannot see it! The opposite occurs at Full Moon: at Full Moon the Moon is in the opposite direction from the Sun. Therefore, as the Sun sets, the Full Moon rises, and vice versa. The Sun reaches its highest point in the sky at noon each day. The Full Moon will reach the highest point in the sky at midnight. At First and Third quarters, the Moon-Earth-Sun angle is a right angle, that is it has an angle of  $90^\circ$  (positions 3 and 6, respectively, in the diagram for exercise #2). At these phases, the Moon will rise or set at either noon, or midnight (it will be up to you to figure out which is which!). To help you with exercises 4 through 6, we include the following figure detailing *when the observed phase is highest* in the sky.



#### 4.1 Exercise 4 (6 pts)







In the set of figures below, the Moon is shown in the first quarter phase at different times of the day (or night). Assume that sunset occurs at 6 p.m. and that sunrise occurs at 6 a.m.

 <div style="text-align: center;"> <div style="display: flex; justify-content: space-between; width: 100%;"> <span>EAST</span> <span>SOUTH</span> <span>WEST</span> </div> <p><b>Time:</b> _____</p> </div>	 <div style="text-align: center;"> <div style="display: flex; justify-content: space-between; width: 100%;"> <span>EAST</span> <span>SOUTH</span> <span>WEST</span> </div> <p><b>Time:</b> _____</p> </div>
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**Instructions:** Determine the time at which each view of the Moon would be seen, and write it on each panel of the figure.

## 4.2 Exercise 5 (6pts)

In the set of figures below, the Moon is shown overhead, at its highest point in the sky, but in different phases. Assume that sunset occurs at 6 p.m. and that sunrise occurs at 6 a.m.







 <div>EAST      SOUTH      WEST</div> <p><b>Time:</b> _____</p>	 <div>EAST      SOUTH      WEST</div> <p><b>Time:</b> _____</p>
 <div>EAST      SOUTH      WEST</div> <p><b>Time:</b> _____</p>	 <div>EAST      SOUTH      WEST</div> <p><b>Time:</b> _____</p>
 <div>EAST      SOUTH      WEST</div> <p><b>Time:</b> _____</p>	 <div>EAST      SOUTH      WEST</div> <p><b>Time:</b> _____</p>

**Instructions:** Determine the time at which each view of the Moon would have been seen, and write it on each panel of the figure.



### 4.3 Exercise 6 (6 pts)

In the two sets of figures below, the Moon is shown in different parts of the sky and in different phases. Assume that sunset occurs at 6 p.m. and that sunrise occurs at 6 a.m.

 <div style="text-align: center;">             EAST      SOUTH      WEST           </div> <p style="text-align: center;"><b>Time:</b> _____</p>	 <div style="text-align: center;">             EAST      SOUTH      WEST           </div> <p style="text-align: center;"><b>Time:</b> _____</p>
 <div style="text-align: center;">             EAST      SOUTH      WEST           </div> <p style="text-align: center;"><b>Time:</b> _____</p>	 <div style="text-align: center;">             EAST      SOUTH      WEST           </div> <p style="text-align: center;"><b>Time:</b> _____</p>
 <div style="text-align: center;">             EAST      SOUTH      WEST           </div> <p style="text-align: center;"><b>Time:</b> _____</p>	 <div style="text-align: center;">             EAST      SOUTH      WEST           </div> <p style="text-align: center;"><b>Time:</b> _____</p>

**Instructions:** Determine the time at which each view of the Moon would have been seen, and write it on each panel of the figure.

## 4.4 Additional Question

After you have completed the six Exercises and are comfortable with Moon phases, and how they relate to the Moon's orbital position and the time of day that a particular Moon phase is highest in the sky, you will be verbally quizzed by your instructor (*without the Exercises available*) on these topics. You will use the dual-colored sphere, and the flashlight, and a person representing the Earth to illustrate a specified Moon phase (appearance of the Moon in the sky). You will do this for three different phases. **(18 points)**

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## 4.5 Take-Home Questions

The following questions are worth **11 points** each.

1. If the Earth was one-half as massive as it actually is, how would the time interval (number of days) from one Full Moon to the next in this ‘small Earth mass’ situation compare to the actual time interval of 29.5 days between successive Full Moons? Assume that all other aspects of the Earth and Moon system, including the Moon’s orbital semi-major axis, the Earth’s rotation rate, etc. do not change from their current values.
2. What (approximate) phase will the Moon be in next Wednesday?
3. If you were on Earth looking up at a Full Moon at midnight, and you saw an astronaut at the center of the Moon’s disk, what phase would the astronaut be seeing the Earth in? **Draw a diagram to support your answer.**

## **4.6 Possible Quiz Questions**

- 1) What causes the phases of the Moon?
- 2) What does the term “New Moon” mean?
- 3) What is the origin of the word “Month”?
- 4) How long does it take the Moon to go around the Earth once?
- 5) What is the time interval between successive New Moons?

## **4.7 Extra Credit (5 pts)**

Write a one page essay on the term “Blue Moon”. Describe what it is, and how it got its name.