Name: ____________________

Astronomy 101 Lab: Lunar Phases and Eclipses

Pre-Lab Assignment: In this week's lab, you will be using a lamp, a globe, and a ball to simulate the Sun, Earth, and the Moon. You will be able to see the relative positions of these objects during each lunar phase. You'll also learn how the elliptical orbit of the Moon affects the type of eclipse we see from Earth. Answer the following questions before coming to lab.

For the first two questions, you will find this information in the appendices of your textbook.

A) What is the average Earth-Moon distance in kilometers? In the lab, this will be called the semi-major axis of the Moon's orbit. Round your answers to the nearest hundred kilometers. For example, 45,678 would round to 45,700.

B) What is the orbital eccentricity for the Moon?

C) Consult the definition of eccentricity given in the lab procedure, which is located next to the ellipse figure. Based on the definition of eccentricity, draw an ellipse with a low eccentricity. Draw an ellipse with a very high eccentricity.

D) Explain how angular size relates to distance. In other words, how does the apparent size of an object change as the object moves toward you and away from you?

Objective: In this lab, you will study the relative positions of Earth, the Moon, and the Sun for the different lunar phases and their rise and set times. In the last part of the lab, you will consider how Earth, the Moon, and the Sun must be arranged to produce lunar and solar eclipses. **Answer the questions in the spaces provided and submit the lab to the instructor before you leave.**

A. Lunar phases: The Earth globe is placed approximately four feet from the light source, which will represent the Sun. The Moon has approximately one-fourth of the diameter of Earth. Thus, a 3"-diameter ball is close to the scaled size of the Moon with respect to the Earth globe. **However, the distances between the Moon and Earth and between Earth and the Sun will not be to scale in this lab.**

The Moon revolves around Earth in a counterclockwise direction, as viewed from above Earth's North Pole. Start by holding the Moon between Earth and the Sun a foot away from Earth. Have one person move the Moon slowly around Earth while the others see what the Moon looks like from Earth by looking over the top of the Earth globe. Be sure to keep the Moon and Earth out of each other's shadows, since eclipses are rarer than our improperly scaled model would have us believe.

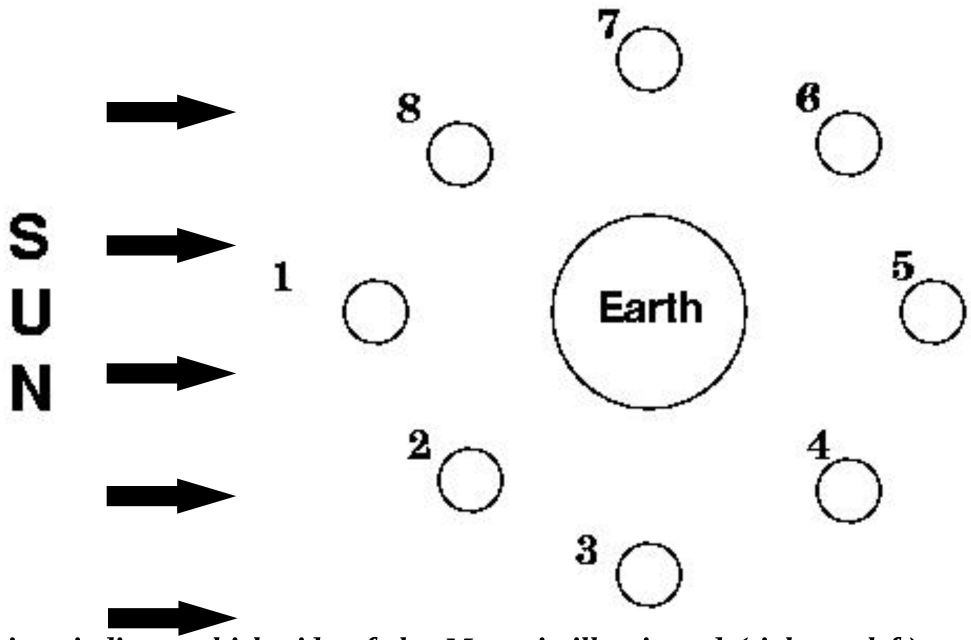
Watch for the following phases to appear: *full moon, waning gibbous, third or last quarter, waning crescent, new moon, waxing crescent, first quarter, and waxing gibbous*.

1. Imagine you were on the Sun. Which lunar phase would you see when looking from there?

The diagram to the right is labeled with the position of Earth, the direction of the Sun, and several different positions for the Moon labeled 1-8.

2. For each circle, shade in the part of the Moon or Earth that is <u>not</u> illuminated by the Sun as you would see it <u>from above</u>.

3. For each position of the Moon in the diagram, record the phase and a brief description of how the Moon appears <u>from Earth</u> in the table below. For each description, indicate which side of the Moon is illuminated (right or left), and approximately how much of the disk is lit. For example, <u>"right side less than half lit"</u> is a sufficient description.



Position	***Phase***	***Description***
1		
2		
3		
4		
5		
6		
7		
8		

4. Imagine you were on the Moon looking at Earth from position 7. Based on the illumination, what phase would Earth look like?

Before going further, review what was covered during the Seasons lab. Identify the regions on Earth experiencing sunrise, noon, sunset, and midnight based on their position in relation to the Sun.

Place the Moon in its "new moon" position, but imagine it to be much farther away from the Earth globe than where you held it before.

5. Determine the time of day (sunrise, noon, sunset, and midnight) that a New Moon would rise and the time of day that it would set. Repeat this for the other major phases and record it in the table.

Phase	***Rise***	***Set***
New Moon		
First Quarter		
Full Moon		
Third Quarter		

6. During which phase is the Moon not above the horizon during the day? ______________________

7. During which phase is the Moon only above the horizon in the A.M.? ______________________

8. Use the information from the two tables above to determine the time of day at which each of the events in the table will occur. For each answer, choose one of the following: "between sunrise and noon", "between noon and sunset", "between sunset and midnight", or "between midnight and sunrise". Note when the event mentions that the Moon is rising or setting.

Waxing Crescent Moon Rises	
Waxing Gibbous Moon Sets	
Waning Gibbous Moon Rises	
Waning Crescent Moon Sets	

B. Eclipses: The Sun is the light source for all objects in the Solar System. When one object passes in front of another such that the sunlight is blocked, we say that an eclipse is occurring. A solar eclipse occurs when the Moon blocks sunlight from reaching Earth. As seen from Earth, it makes it look like the Sun has become darker, thus the name solar eclipse. A lunar eclipse occurs when Earth blocks sunlight from reaching the Moon, making the Moon appear darker.

9. During which lunar phase can a solar eclipse occur? ______________________

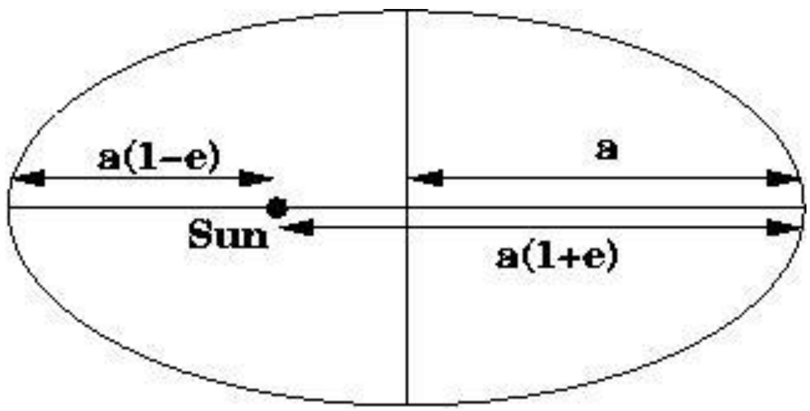
10. During which lunar phase can a lunar eclipse occur? ______________________

11. During a lunar eclipse, does the Moon enter Earth's shadow from the east or the west side of the shadow? Explain your answer.

12A. Imagine you were on the near side of the Moon. Are solar eclipses possible when observing from the near side? Explain your answer.

12B. Imagine you were on the far side of the Moon. Are solar eclipses possible when observing from the far side? Explain your answer.

C. Distance to the Moon: Orbits of the planets around the Sun and the orbit of the Moon around Earth are not circles, they are ellipses. The exaggerated shape of a planetary orbit is shown below. The Sun is at a point in the ellipse called a **focus**. All ellipses have two such points.



The shape of an ellipse can be described with two parameters: the semi-major axis, *a*, and the eccentricity, *e*. The eccentricity tells us how much the ellipse deviates from a circle. The closer the value is to zero, the closer the ellipse is to being a perfect circle.

When the planet is closest to the sun, we say that the planet it is at perihelion (from "helios", meaning "Sun"). The perihelion distance is given by $a \times (1 - e)$, as shown in the diagram. Similarly, when the planet is farthest from the Sun, we say that the planet is at aphelion. The aphelion distance is given by $a \times (1 + e)$.

The orbit of the Moon around Earth is an ellipse, like a planet's orbit around the Sun. For an orbit around Earth, we use the term "perigee" to denote the point on the orbit closest to Earth and "apogee" to denote the point on the orbit farthest from Earth. In the pre-lab assignment, you were told to look up the semi-major axis of the Moon's orbit and its orbital eccentricity. Use the equations from above: $a \times (1 + e)$ gives the apogee distance and $a \times (1 - e)$ gives the perigee distance.

13. Calculate the distance from Earth to the Moon at perigee and at apogee. Round your answers to the nearest km.

Moon at perigee: ___________________________ km

Moon at apogee: ___________________________ km

When looking at objects in the sky, we often talk about their size in terms of the angle that they subtend in the sky, i.e. the angular size of the object. We can calculate the angular size of the Moon in radians by taking its diameter and dividing it by the distance to the Moon. However, what we will find is that the value we come up with is very small; a radian is roughly 57° and we know that the Moon takes up a much smaller angle in the sky. We will therefore express our answers in arcseconds, using the fact that there are 206,265 arcseconds in a radian.

To find the angular size in arcseconds, use the following equation:

Angular size of the Moon in arcseconds = (Diameter of Moon / Distance to Moon) × 206,265

14. Calculate the angular size of the Moon at perigee and at apogee using the distances you calculated and the Moon's diameter, 3,476 km. Round your answers to the nearest arcsecond.

Angular size of the Moon at perigee: ___________________________ arcseconds

Angular size of the Moon at apogee: ___________________________ arcseconds

15. Earth's orbit is nearly circular, so we will assume that the distance from Earth to the Sun is nearly always the average distance. Use the information given below to calculate the angular size of the Sun the same way you did for the Moon.

Diameter of the Sun = 1,392,000 km
Average distance from Earth to the Sun = 149,600,000 km

Angular size of the Sun: ___________________________ arcseconds

To get a total solar eclipse, the angular size of the Moon must be larger than the angular size of the Sun. If the angular size of the Moon is smaller than the angular size of the Sun, you will see an eclipse in which the outer edge of the Sun is still visible around the Moon, called an annular eclipse.

16. Based on your calculations and what you know about lunar phases, complete the following statements.

For a total solar eclipse, the lunar phase must be ______________ and the Moon must be near ***apogee / perigee (circle one)*** in its orbit around Earth.

For an annular solar eclipse, the lunar phase must be ______________ and the Moon must be near ***apogee / perigee (circle one)*** in its orbit around Earth.

For your last step, you will sketch an annular solar eclipse on the back of the page. You must make the diagram to scale, so you will need a compass for this.

To make the drawing, we will need to scale the Sun and Moon so that they will fit on the paper. Based on your answer to the angular sizes of the Moon, start by figuring out whether you should use your angular size value for perigee or apogee. Then, find the scaled size of the Moon in your figure by using the following equation:

Scaled diameter in cm = angular size in arcseconds / 200

17. Calculate the scaled diameter of the Moon and the Sun. Record your answers in the spaces below. Round your answers to the nearest 0.1 cm.

Scaled diameter of the Moon: _________________________

Scaled diameter of the Sun: _________________________

Start by drawing the Sun using the compass on your table. Since a compass draws a circle for a set *radius*, you should use the ruler to **set the width to half of the value** you found above.

18. When you are ready, use the back of this page, place the compass point at the center of the page, and draw the circle for the Sun, making sure that it stays on the page. Reset the compass to the scaled radius for the Moon and repeat the procedure to draw the disk of the Moon, using the same center point you used to draw the Sun. When you are finished, take a pencil and lightly shade in the Moon. You now have a scaled drawing of an annular eclipse.