

ES 104 Laboratory # 1 MODELS AND SYSTEMS

Introduction

We use models to represent the natural world in which we reside. Throughout human history, models have also been used to represent the solar system. From our reality here on Earth, we take part in an Earth-Moon-Sun system. The relationship between their positions at various times determines some common phenomena such as seasons, moon phases, and day length. In this lab, you will use physical models to explore these relationships.

Goals and Objectives

- Create scale models and make sketches that reasonably portray observations of components of the Earth-Moon-Sun system
- Use physical models to determine the reasons for the phases of the moon, the seasons, and the length of the day

Useful websites

- <http://home.hiwaay.net/~krcool/Astro/moon/moonphase>
- <http://www.ac.wvu.edu/~stephan/phases.html>
- <http://csep10.phys.utk.edu/astr161/lect/index.html>
- <http://www.astro.uiuc.edu/projects/data/Seasons/seasons.html>

Name _____ KEY _____
 Lab day _____ Lab Time _____

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the following terms as related to systems:

A. Open System

A SYSTEM THAT CAN FREELY EXCHANGE MATTER AND ENERGY FROM OUTSIDE THE BOUNDARIES OF THE SYSTEM

B. Closed System

A SYSTEM THAT CAN EXCHANGE ENERGY BUT NOT MATTER FROM OUTSIDE THE BOUNDARIES OF THE SYSTEM

2. Is the Earth an open or closed system? Why?

EARTH IS ESSENTIALLY A CLOSED SYSTEM, THAT EXCHANGES ENERGY, BUT ALMOST NO MATTER, FROM OUTSIDE ITS BOUNDARY

3. What is the distance from the Earth to the Moon? How long does it take the Moon to revolve around the Earth?

MOON IS ON AVERAGE 384,401 KM FROM EARTH, VARYING FROM 361,337 TO 407,465 KM.

MOON TAKES $27\frac{1}{3}$ DAYS TO ORBIT EARTH. IT IS 29.5 DAYS TO GO COMPLETELY THROUGH ITS SET OF PHASES, BACK TO ITS STARTING PHASE.

4. Define the following terms (draw diagrams to illustrate your answers):

A. Waxing moon THE CHANGE FROM NEW TO FULL, WHERE A GREATER PORTION OF MOON IS ILLUMINATED EACH EVENING.

B. Waning moon THE CHANGE FROM FULL TO NEW, WHERE A LESSER AMOUNT OF MOON IS ILLUMINATED EACH EVENING.

C. Full Moon WHEN MOON IS COMPLETELY ILLUMINATED.

D. New Moon WHEN NONE OF MOON IS ILLUMINATED.

5. What is the difference between “waning moon” and “third quarter phase”? MOON LOOKS TO BE A ‘HALF MOON’ AT THE THIRD QUARTER PHASE; IT IS WANING IN THE THIRD QUARTER, BUT WANING LASTS FROM FULL THROUGH $\frac{3}{4}$ TO NEW.

Part A - A Model of the Sun-Earth-Moon System

Phases of the Moon

You will construct a physical model of the Sun-Earth-Moon system. Materials for your model will be at the appropriate activity station. The purpose of this model is to investigate the **phases of the moon**, which include new, first quarter, full, and third-quarter (or last-quarter). Refer to your textbook (Fig. 20.23, p. 568, *Earth Science*, Tarbuck and Lutgens, 11th ed.) to see how they appear in the sky.

Use a small sphere affixed to a stick to model the moon. Figures 2, 4, 6 and 8 represent the view of the model as if you were far from Earth, but above the North Pole. A lamp acts as Sun. Position Moon, Earth and Sun (lamp) at the locations indicated in figures, placing Earth about half a meter (50 cm) from Sun.

On Figure 2, blacken in the shadowed part of the moon.

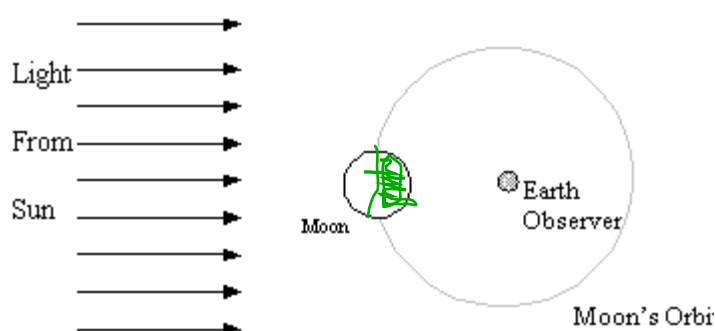


Figure 2: A top view of the Sun-Earth-Moon model.

Locate the 'observer on a stick' cut out and use the 'observer' to represent you standing on Earth's surface. This observer represents how "we" here in Monmouth, Oregon would view the moon phases. Your job is to deduce what the 'observer on a stick' located on Earth will see. On Figure 3, **blacken in the shadow of the moon's face** that the 'observer on Earth' sees when looking into the sky.



The **phase** (see above) of the moon is

NEW

Figure 3: The way a person on Earth would observe the moon.

Figure 4 represents another top view of the model. Holding Moon at the new location as indicated below, **blacken in the shadowed part of the moon.**

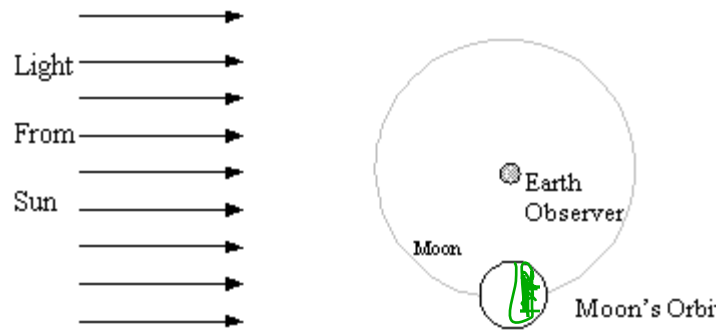


Figure 4: A top view of the Sun-Earth-Moon model.

What does the 'observer on a stick' see now? To indicate this, **blacken in the shadow of the moon's face in Figure 5.**



The phase of the moon is

Figure 5: The way a person on Earth would observe the moon.

-----**FIRST QUARTER**-----.

Blacken in the shadowed part of the moon in figure 6.

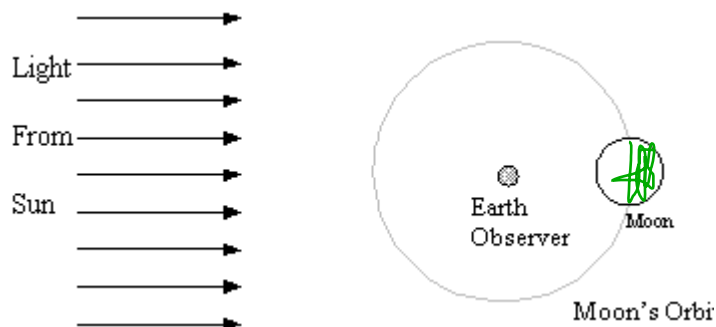
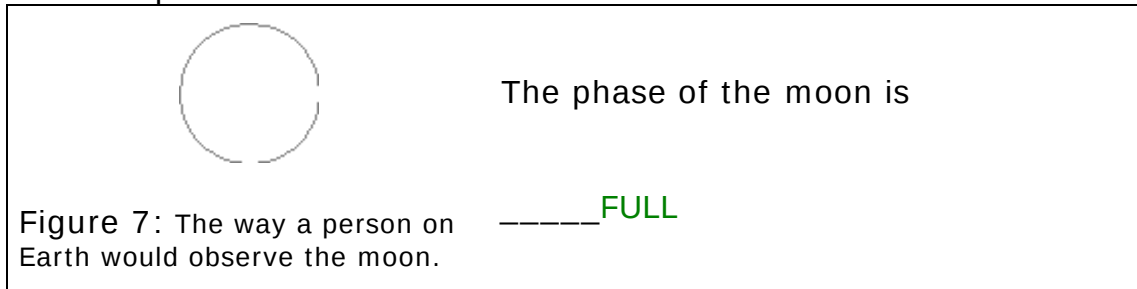
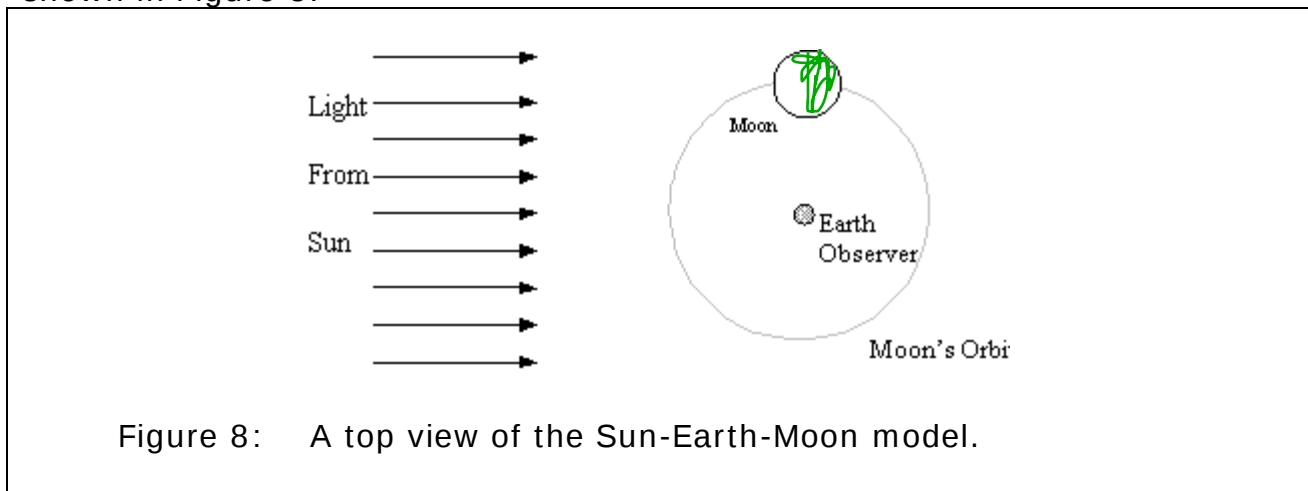


Figure 6: A top view of the Sun-Earth-Moon model.

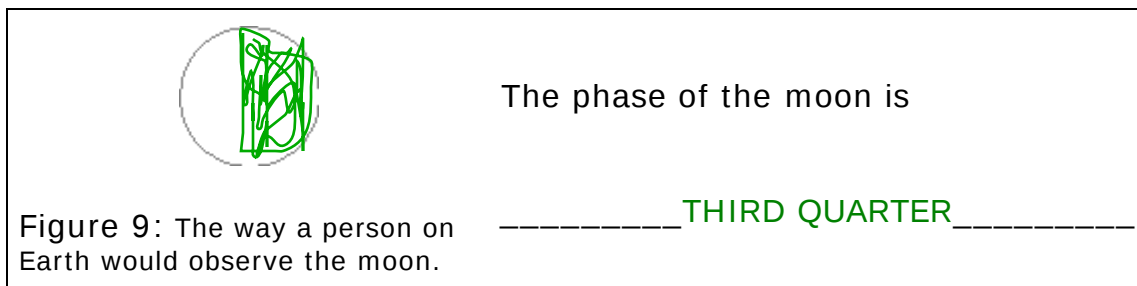
Again, **blacken in the shadow of the moon's face** in Figure 7 when it is in the above position.



Once more **blacken in the shadowed part of the moon** when it is located as shown in Figure 8.



When an observer looks into the sky, what will they see when the moon is located as it is in Figure 8? Indicate what they see in Figure 9, below.



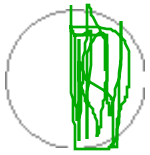
Mental Exercise:

Now construct drawings 3A, 5A, 7A, and 9A for an observer viewing Moon from the Southern Hemisphere (for example, from a position “down under” in Australia). To model this **new frame of reference**, take your observer on a stick and “walk” them down to Australia when Moon is in the locations shown in Figures 2, 4, 6, and 8. (Note the observer should now be “up-side-down.”). In the spaces provided below, **draw the four corresponding Moon views for this new observer position.**



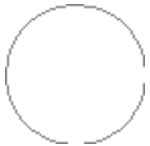
The phase of the moon is

Figure 3A: How a person on the Earth in **Australia** would observe the moon. _____ **NEW** _____.



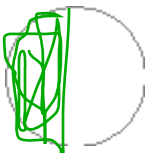
The phase of the moon is

Figure 5A: How a person on the Earth in **Australia** would observe the moon. _____ **FIRST QUARTER** _____.



The phase of the moon is

Figure 7A: How a person on the Earth in **Australia** would observe the moon. _____ **FULL** _____.



The phase of the moon is

Figure 9A: How a person on the Earth in **Australia** would observe the moon. _____ **THIRD QUARTER** _____.

Questions:

1. Assuming the Earth-Moon-Sun position is the same, does the phase of the moon change when viewed from the Northern Hemisphere compared to the Southern Hemisphere? If we in Monmouth, Oregon view a first quarter moon phase, what phase will people in Australia view when they see the moon on the same evening? Consider whether Moon's position with respect to Earth (Figures 2, 4, 6, and 8) is the same whether you are in Australia or Oregon.

THE PHASE STAYS THE SAME. THE PERSONAL REFERENCE POINT, WHICH SIDE (LEFT OR RIGHT) THAT APPEARS TO BE ILLUMINATED IS DIFFERENT IN AUSTRALIA FROM MONMOUTH, BUT IT IS A WAXING MOON IN EITHER PLACE.

2. What is the time in days between two successive full moons (i.e., from one full moon to the next full moon)?

29.5 DAYS

3. What is the time in days between a full moon and a new moon?

14.75 DAYS

4. What is the orbital period of Moon around Earth (in days)?

27 1/3 DAYS

5. How long does it take Moon to move around Sun (in days)?

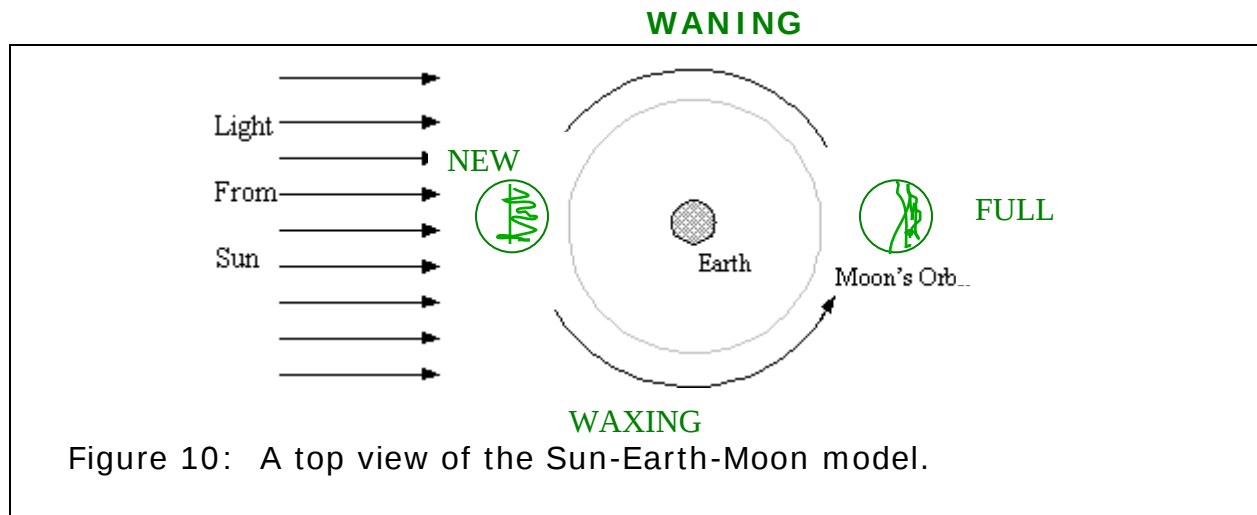
365 DAYS

6. If the full moon is on the western horizon, approximately what time of day must it be? HINT: Where is Sun in relation to you when you are gazing westward at a full Moon?

The time of day will be _____DAWN_____.

(Generally speaking, such as: mid-morning, sunset, dawn, noon, midnight, etc.)

Draw in and label the locations of the **full moon** and the **new moon** in Figure 10. **Fill in the shadowed part of Moon** in each case. (HINT: use Figures 2 and 4 as a guide.) **Label one curved arrow *waning*** -- where Moon is getting closer to a new moon. **Label the other curved arrow *waxing*** -- where it is building up to a full moon.



7. Write a brief explanation as to why we see the phases of the moon.

MOON ORBITS EARTH, AND IS SOMETIMES BETWEEN EARTH AND SUN, SOMETIMES ON THE OPPOSITE SIDE FROM SUN, AND SOMETIMES BESIDE EARTH. ALTHOUGH HALF OF MOON IS LIGHTED, AND HALF IS IN SHADOW AT ANY TIME, WE SEE ONLY ONE SIDE OF MOON, AND OFTEN SEE PART LIGHTED AND PART SHADOW.

8. The color of material (rock and dust) that covers the moon is primarily light colored. Suppose all of Moon's material was black. Would we see moon phases? Explain.

WE PROBABLY COULD SEE MOON, BUT IT WOULD BE MUCH DIMMER THAN IT APPEARS WITH MOSTLY LIGHT MATERIAL ON THE SURFACE. If you think you cannot see Moon, remember to mention it would block stars.

9. Assume you are "camped" on Moon closest to Earth for a one-month stay. Will you be able to see Earth? Will there be phases of Earth, as we see Moon phases? Explain. (HINT: use your observer and model.)

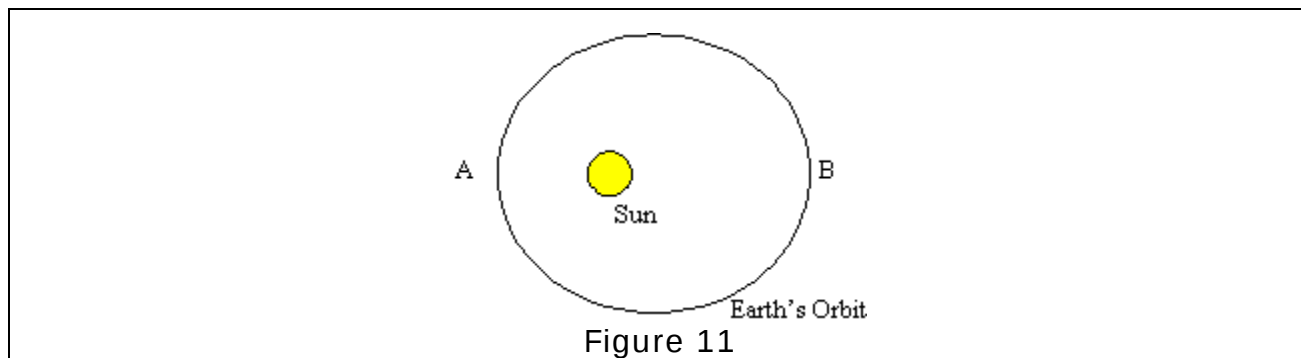
WE WOULD SEE EARTH IN THE LUNAR SKY, AND WE WOULD SEE PHASES AS WE ORBIT EARTH TO SEE VARIOUS ASPECTS LIGHTED AND IN SHADOW FROM SUN'S LIGHT.

Part B – The Seasons

The Baroque composer Antonio Vivaldi wrote a pervasively familiar set of concertos called "The Seasons". Each of the set of four is devoted to one of the four seasons -- spring, summer, and autumn, winter. Concerto No. 1 mimics songs of birds, spring thunderstorms, and a spring zephyr. In the summer concerto, Vivaldi uses changes of meter (first $3/8$ and later $4/4$ time) to describe the exhaustion caused by the summer heat. Autumn, the season of harvest, Vivaldi uses the motifs of a tribute to Bacchus -- God of Wine -- via a feverish dance and The Hunt using the horns to herald the event. In Concerto No. 4, the frigid winds blow in an almost melody-less illustration.

The Venetians of Vivaldi's time all understood the effects and moods of the seasons, but how did they come about? In this activity, we look closely at an explanation.

First, we must dispel an old misconception. Figure 11 shows a sketch of Earth's orbit from a top view far above Sun. The orbit of Earth is not a perfect circle, it's a 'squashed circle'; the orbit is slightly elliptical. However, the 'squashed-ness' of the orbit -- its *eccentricity* -- is greatly exaggerated in Figure 11. **The common misconception is that when Earth is at point A (where it is closer to Sun) it is summer on Earth.** If you have ever gone to South America or Australia in January (our winter), you would discover it is summer there! The misconception would have it summer in both the northern and southern hemispheres when Earth is closest.



The common misconception fails on another point. The orbit of our planet is so close to a perfect circle that you probably cannot draw a circle on paper more circular than Earth's orbit -- not even with a compass! The *eccentricity* of Earth's orbit is 0.0167. The *eccentricity* of perfectly circle is zero, whereas a 'flattened circle', flattened until it is just a line, has an *eccentricity* of one. The eccentricity of our orbit is much closer to zero than to one, nearly a perfect circle.

Activity 1: Investigate Figure 12, which shows Earth with incoming solar radiation. Earth's radius is about 3884 miles.

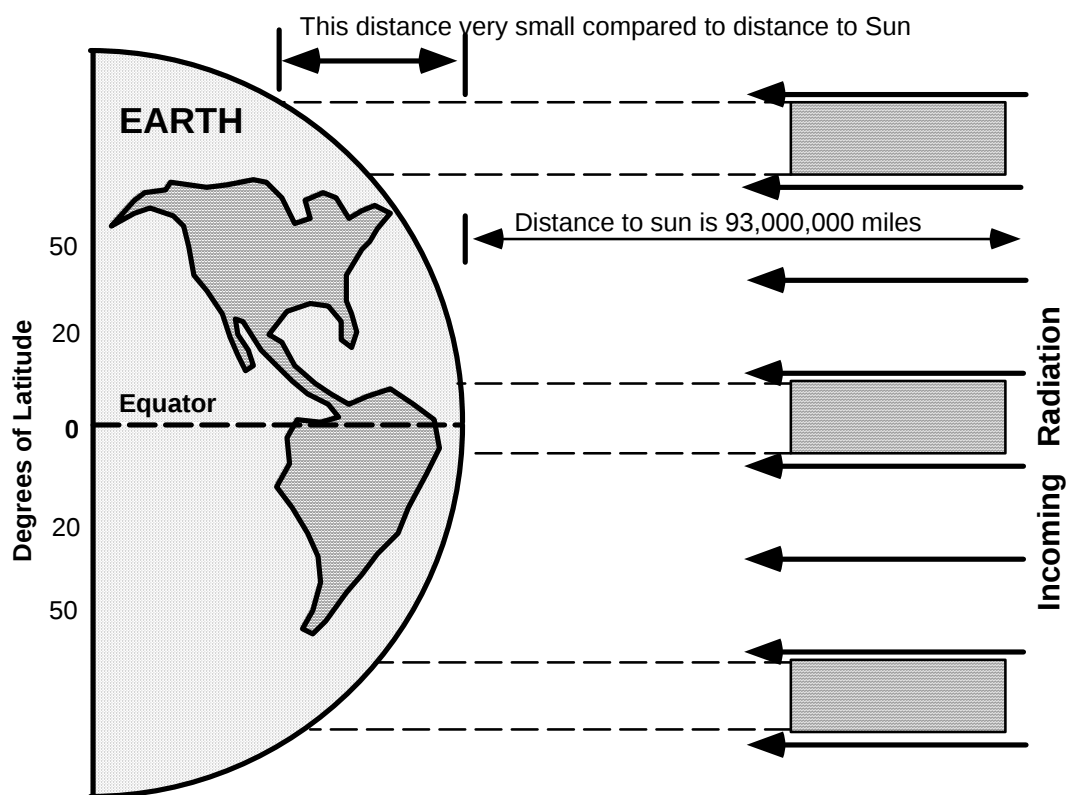


Figure 12: Schematic representation of Earth-Sun system emphasizing input of solar radiation.

Many people have the conception that the Polar Regions are cooler than the equator because they are further away and therefore the Sun's energy is "weaker" when it strikes the Polar Regions. Let's explore this reasoning.

1. Briefly speculate on why Earth heats up more at the equator than closer to the north or south poles. HINT: See Figure 12, and note the shaded bands of incoming radiation at the equator (middle band), and in the mid latitudes (upper and lower bands).

$$\frac{4000}{93,000,000} \times 100 = 0.0043\%$$

2. The Sun is 93,000,000 miles away from the equator. The radius of Earth is a little less than 4000 miles. How much further (in percent) does the energy of Sun have to travel before reaching the polar region? Show your calculations.
3. How important do you think this added distance (4000 miles) is in temperature between the poles and equator? Consider the value calculated in question 2 above, the percent difference in distance.

SEEMS LIKE AN INSIGNIFICANT AMOUNT OF DISTANCE, LOOKING AT THE PERCENTAGE IN THE CALCULATIONS ABOVE.

Now examine a model of Sun's energy striking Earth. Use a light is positioned several inches away from the equator of a globe. With a piece of graph paper, measure the area of light striking the globe at the equator and at the polar region.

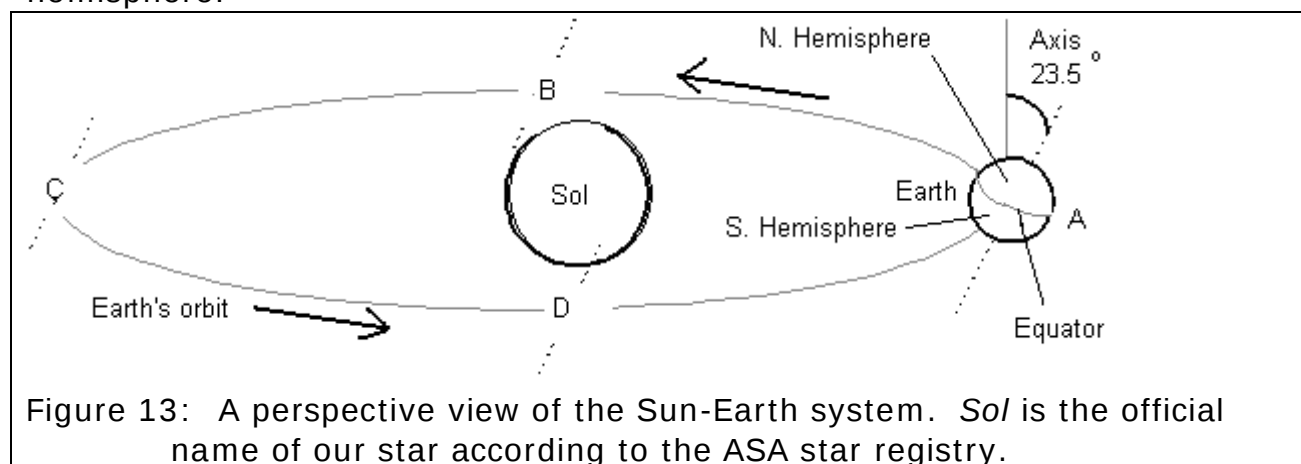
4. Are the two areas equal?

THE POLAR AREA IS MUCH LARGER THAN THE EQUATORIAL AREA

5. Now suggest a reason why the poles may be cooler than the equator regions.
THE ENERGY IS MORE CONCENTRATED IN THE EQUATORIAL AREAS, AND MORE SPREAD OUT IN THE POLAR AREAS. THE SAME AMOUNT OF ENERGY HAS TO GO OVER A MUCH LARGER AREA IN THE POLES, AND CANNOT HEAT AS MUCH.

Activity 2: Use a 'sphere on a stick' as Earth and a lamp as Sun to 'build' a Sun-Earth system model. The model will not be to scale. It should look something like Figure 13 on the following page.

Successively place 'Earth' at locations A, B, C, and D. **Note that the direction of the tilt of the axis of Earth should not change. The axis will always lie along the same line as indicated.** (This is a result of conservation of angular momentum -- it is the same reason why the axis of a gyroscope will always tend to point along the same line.). Deduce what season it must be in the northern hemisphere.



Questions:

1. Complete the table using your observations:

Location of Earth in Figure 13	Season in the Southern Hemisphere	Season in the Northern Hemisphere
A	SUMMER	WINTER
B	FALL	SPRING
C	WINTER	SUMMER
D	SPRING	FALL

2. During which season(s) does more direct or concentrated sunlight (and therefore more infrared radiation) hit the surface of Earth at the following locations?

Monmouth, Oregon

SUMMER

The Equator

SPRING AND FALL

3. Why do the northern and southern hemispheres have opposite seasons?

EARTH'S AXIS POINTS TOWARD POLARIS ALL YEAR

Activity 3: Examine the two models provided, Model A and Model B. Complete the table by answer the questions for each model.

	<u>MODEL A</u>	<u>MODEL B</u>
What does the model demonstrate?	THE RELATIONSHIP OF SUN, EARTH AND MOON. THE SEASONS; MOON'S PHASES	HOW THE STARS AND PLANETS APPEAR FROM EARTH
What does each part of the model represent?	SUN, EARTH AND MOON AND THE LIGHTED AND UNLIGHTED SIDE OF MOON	EARTH, ORBITING MOON, (OR PLANET IN A PTOLEMAIC MODEL OF THE SOLAR SYSTEM) FIXED CELESTIAL SPHERE.
What is distorted or "misrepresented" in this model?	SIZES OF BODIES, DISTANCES OF BODIES, ORBITAL PLANES OF BODIES, SHAPE OF ORBIT OF BODIES	DISTANCES TO START
What are the limitations for this model?	INDICATES ECLIPSES OCCUR MONTHLY	DOES NOT SHOW PROPER STELLAR RELATIONSHIP

Name _____ KEY _____

Lab day _____ Lab Time _____

POST-LAB ASSESSMENT

No scientific hypotheses or models represent all aspects of a system with 100% accuracy. To make systems understandable, all scientific models and hypotheses make simplifying assumptions. These simplifying assumptions can often lead to shortcomings of a model. Consider the model of the Sun-Earth-Moon system that you used to understand the phases of Moon.

1. How often does this model predict that solar eclipse and lunar eclipses should occur?

PREDICTS ECLIPSES EVERY ORBIT OF MOON.

2. What simplifying assumption in our model results in this erroneous prediction?

ASSUMES ORBIT OF EARTH AND MOON PARALLEL TO SUN'S EQUATOR.

3. How could you revise the model to make its predictions of eclipses more accurate?

REVISE BY INCLINING ORBITS OF EARTH TO SUN, AND MOON TO EARTH.

4. Imagine that you want to power your home in Monmouth using solar energy. In order for your solar panels to collect as much energy as possible, what direction should your solar panels face (north, south, east, or west)? _____ **SOUTH** _____ On the picture below, draw your house and the solar panels on it to justify your answer. If you lived in Australia, what side of your house should have the solar panels? _____ **NORTH** _____ Include the Australia house on the picture.

