Name: _____

Astronomy 101 Lab: Seasons

Pre-Lab Assignment: In class, we've talked about the cause of the seasons. In this lab, you will use globes to study the relative positions of Earth and the Sun during the different seasons. Answer the following questions before coming to lab. **This information is not in the textbook; it can be found using the internet or Stellarium.**

A) What is the latitude of the Equator?

B) What are the latitudes of the North Pole and the South Pole?

C) What are the latitudes of both the Tropic of Cancer and the Tropic of Capricorn?

D) What are the latitudes of both the Arctic Circle and the Antarctic Circle?

E) What is the noon-time altitude of the Sun in Champaign on September 21?

Objective: When you have completed this lab, you will be able to describe the seasons of the year and explain the reasons for those seasons. **Answer the questions in the spaces provided and submit the lab to the instructor before you leave.**

You will use globes, lights, and a mechanical model to study the seasons on Earth. **Remember, the distance of the globe to the light is not to scale!** Earth is much farther away from the Sun and much smaller in relationship to the Sun than the model shows. Also, the word "seasons" suggests a change in the average weather from one time of year to another.

A. The position of the Sun at various times of day: The Earth globe should be approximately four feet from the light source. The axis of the globe should be aligned with the edge of the shadow, and Illinois should be facing toward the spotlight (the Sun). With the globe in this position, turn on the Sun, and answer the following questions based on your observations.

1. Which continents are experiencing daytime? _____

2. Which continents are experiencing nighttime? _____

3. Approximately what time is it in Illinois (sunrise, noon, sunset, or midnight)? _____

4. Approximately what time is it in India? _____

On the globe, you will find that there is a line that separates day and night: the **terminator**. At any location along this line, the Sun will be on the horizon. On one side of the globe, the terminator line shows where it is sunrise and on the other side of the globe, the terminator shows sunset.

Earth rotates counterclockwise, as viewed from above Earth's North Pole. While looking down at the globe from above, spin the globe counterclockwise so you can get a feel for which side of Earth is experiencing sunrise and which side of Earth is experiencing sunset. When you are done, position Illinois so that it is again facing the Sun.

With Illinois facing the Sun,

5A. name a place on the globe where the Sun is rising. _____

5B. name a place on the globe where the Sun is setting. _____

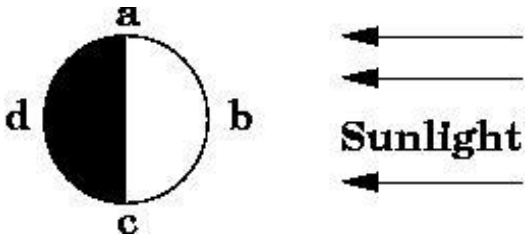
What time of day is it at each of the positions a, b, c, and d in the figure at the bottom right? Use the terms "midnight," "noon," "sunrise," and "sunset." Assume that you are looking down at the North Pole as you did when spinning the globe.

6A. _____

6B. _____

6C. _____

6D. _____



B. The altitude of the Sun at noon: Consider the different places on the globe where it is noon. These will be along a line between each pole. You can understand the altitude of the Sun at any location by placing a golf pencil on that spot, standing up. The pencil will cast a shadow on the globe unless the Sun is directly overhead or at the horizon.

7. What is the name given to the latitude where the Sun would be seen directly overhead at noon? (These names were covered in the pre-lab.)

_____

What is the latitude of this position? _____

8. What is the name given to the latitude where the Sun can be seen on the horizon at noon? (There are two possible answers.)

_____

What is the latitude of one of these places? _____

Important: Convince yourself that for 10° latitude, the noon-time altitude of the Sun would be 80° and for 30° latitude, the noon-time altitude of the Sun would be 60° (always 90° – latitude) on the equinox. For our latitude of 40°, the noon-time altitude of the Sun would be 50°, as you should have answered in the pre-lab.

C. Inclination (tilt) of Earth in summer: The Earth/Sun model we've used does not conform to reality. The orientation of Earth's axis usually favors one pole over the other. Orient the globe so that the North Pole is facing toward the Sun. This represents the sky at noon on or near June 21, the summer solstice for the northern hemisphere. Use the golf pencil to find the position on the globe where the Sun is directly overhead at noon.

9. What is the name given to this latitude? _____

What is the latitude at this position? _____

10. How many hours per day does the North Pole receive sunlight? _____

11. How many hours per day does the South Pole receive sunlight? _____

At our latitude of 40°, the Sun is 23.5° higher at noon than on September 21.

12. What is the noon-time altitude of the Sun in Champaign on June 21? _____

D. Inclination of Earth in winter: Now tilt the North Pole away from the Sun. This represents the sky at noon on or near December 21, the winter solstice for the northern hemisphere. Find the position on the globe where the Sun is directly overhead at noon.

13. What is the name given to this latitude? _____

What is the latitude at this position? _____

Notice that the South Pole receives 24 hours of sunlight, and the North Pole receives none. Find the lowest latitude where the Sun never rises.

14. What is the name given to this latitude? _____

What is the latitude at this position? _____

For residents of Champaign at noon on December 21, the noon-time altitude of the Sun is 23.5° lower than on September 21.

15. What is the noon-time altitude of the Sun in Champaign on December 21? _____

16. Given what you have found out about the seasons and the relative positions of Earth and the Sun, how do the seasons in the Northern Hemisphere compare with those in the Southern Hemisphere? Explain your answer, perhaps by giving an example.

E. Equinoxes: Position the globe so that neither pole is oriented toward the Sun. This is the relative position of Earth and the Sun on the equinox. The spring (vernal) equinox occurs on or near March 21 and the fall (autumnal) equinox occurs on or near September 21 in the northern hemisphere. At these times of year, the hours of daylight and darkness are nearly equal. The term "equinox" means "equal night."

17. For this orientation of the globe, which cardinal direction will the Sun rise from? It may help to point the golf pencil toward the Sun at sunrise to determine the cardinal direction.

_____

Which cardinal direction will the Sun set? _____

We notice that on an equinox, the Sun is directly overhead at noon for somebody living at the equator, just as it was when the globe was not tilted.

18. Suppose that Earth's axis were NOT tilted by 23.5°, but straight up and down with neither pole oriented towards the Sun. Describe the seasons of the year in that case.

F. Why summers are warmer and winters are colder: Now that you've seen where the Sun strikes Earth at different times of the year, you've noticed that the height of the Sun changes for everyone on Earth during the course of the year. It is this change in the height of the Sun that is responsible for the seasons. The changing height of the Sun has two effects: it affects the length of the day and it affects the concentration of sunlight.

Let's start with the length of the day. Start by orienting the globe *with the northern hemisphere tilted toward the Sun*. Use a piece of string to find the length required to circle the globe at 40° North latitude. Use the meter stick to measure the length of the string. Please make all measurements in centimeters.

19. Length of string around 40° North latitude: _____

Consider now only the portion of the 40° North latitude line that is in sunlight. Take the string and measure the section of the 40° north latitude line that is in sunlight.

20. Length of sunlit region at 40° North latitude: _____

We know that a full day is 24 hours long. We can determine the length of the daytime by dividing the length of the sunlit portion by the total length and multiplying by 24. Use the following equation:

$$\text{Length of day} = \frac{\text{Length of sunlit portion}}{\text{Length around 40° North latitude}} \times 24 \text{ hours}$$

21. Length of daytime at 40° North latitude: _____

The globe was oriented so that you were measuring the length of the day on June 21. To determine the true length of the day on June 21, acquire the page from the US Naval Observatory from your instructor. Find the entries for sunrise and sunset and determine the time between them, rounded to the nearest half hour.

22. Actual length of daytime: _____

Use the value you calculated using the length of the string and the actual length you just obtained to calculate a percent error for your measurement. Do this in the following way:

A) [Answer to Question 22] – [Answer to Question 21]
B) [Answer to Part A] ÷ [Answer to Question 22]
C) Percent Error = [Answer to Part B] × 100

Example: Let's say that you obtained 16 hours for question 21 and 15 hours for question 22. Your percent error would be:
A) 15 hours – 16 hours = -1 hour
B) -1 hour ÷ 15 hours = -0.067
C) Percent Error = -0.067 × 100 = -6.7%

Your answer may be positive or negative.

23. Percent error: _____

24. What do you think is the main source of the error you just calculated? (Writing "human error" is not acceptable. Explain how a person would cause such errors.)

25. Estimate the length of daytime at 40° North latitude on December 21. Explain your answer.

26. How does the length of daylight affect the temperature?

What you just saw was that when the northern hemisphere is pointed toward the Sun, the days are long and it is summer there. At the same time, the southern hemisphere is pointed away from the Sun, so the days there are short and it is winter there.

The length of the day is important, but the main reason for the changing seasons is the changing angle at which the sunlight strikes Earth. Find the apparatus which has flashlights mounted at different angles pointed toward the floor. Turn on the higher flashlight. Note that the pattern of the light on the floor is not perfectly circular. Use a meter stick to measure the longer length of the light on the floor.

27. Longer length of the light on the floor from the higher flashlight: _____

The lower flashlight is oriented so that its light is the same distance from the floor it is illuminating. Turn off the higher flashlight and turn on the lower flashlight. Use a meter stick to measure the longer length of the light on the floor. When you are complete, turn off the flashlight.

28. Longer length of the light on the floor from the lower flashlight: _____

You may have noticed that the brightness of the image changed based on the angle of the flashlight.

29. Describe how the brightness of the light changes based on the angle of the light.

30. How does the altitude of the Sun affect the temperature on the ground?

G. Relative positions of Earth and the Sun during the four principal seasons: Find the mechanical model of the Earth/Sun system on the front desk (please ignore the Moon and Venus). Plugging it in will only cause the Sun light up; you still have to move the model manually. Hold the base down and manually push the arm to move Earth around the Sun. Note that Earth's axis maintains the same tilt. It points to the North Celestial Pole (near Polaris) all year long. Watch the seasons progress as Earth's axis changes orientation relative to the Sun's location.

A common misconception is that Earth is closer to the Sun in the summer and that is why summer is warmer. Earth's orbit is nearly circular, but it is actually closest to the Sun (at perihelion) in January. The seasons change because of the changing altitude of the Sun during the year.

31. Describe what happens to the tilt as Earth orbits the Sun. Why do those factors cause the change of seasons?