Astronomy 1 – Introductory Astronomy
Spring 2014

Lab 4: The Seasons

Quick overview

Meet at 8 p.m. in Science Center Room 187. This is an indoor lab – some of the activities will be hands-on and involve a physical model of the Earth (a Styrofoam ball) and the Sun (a light bulb) and other parts of the lab will involve using software that can simulate what the sky looks like at any point on Earth and at any time of day and any day of the year.

Before coming to lab

Read "The Local Sky" on p. 29 of the textbook and study Fig. 2.6 carefully. And also read "The Celestial Sphere" on p. 28 and study Fig. 2.4. (You don't have to read the section on The Milky Way.) Read "The Reasons for the Seasons" on pp. 35-37. And read some of the special section on celestial timekeeping and navigation, specifically: And read pages 88 through the top of p. 93 (but you can skip the mathematical insight on p. 92).

Make sure you understand the following terms (or come to lab ready with questions about those you don't!):
Equinox
Solstice
Ecliptic
Horizon
Meridian

Group Activity: Earth's Orbit

Each group of two has a Styrofoam ball, thumbtack, rubber band, and a dowel or pencil. Carefully stick the dowel all the way through the center of the ball. This represents Earth's rotational axis. Put the rubber band around the ball to represent the equator. Put the tack at approximately 40° above equator to represent our location (Philadelphia is very close to 40° N latitude.)

As a class, gather in a large circle around the light in the center of the room. One person hold the ball, while the other partner takes notes. We will all start with our “Earth's” at the Northern Hemisphere vernal equinox. Tilt your North Pole approximately 23.5º from the vertical to the left, with the ball between you and the “Sun.” The Earth rotates in a counterclockwise direction (while looking down the North Pole), which makes the Sun appear to rise in the east and set in the west.

Your instructor will guide you through the steps of this activity so you do not need to refer to these instructions constantly. Note your observations as you go, but wait until you are back at your tables to carefully answer the questions in bold type.

Rotate ball around the axis so that it is “sunrise” at tack location.
Rotate until it is noon.

Q1. How do you know where it is local noon?

Rotate to “sunset”.
Rotate to midnight.
Note how the length of the tack’s shadow changes as the ball rotates. (You won’t be answering specific questions about the shadow length while doing the procedures in the first part of the lab, but at the end of the first part, you *will* be asked a question about the trends in noontime shadow lengths, so you should pay attention to how the tack’s shadow varies – both over the course of one “day” and at noon at different seasons, or positions in the Earth’s orbit around the Sun.)

Q2. How do you know where it is midnight?

Now, look at the Northern and Southern hemispheres.

Q3. Comment on the relative amounts of light each hemisphere receives over the course of one day at the equinox. Are they the same or does one hemisphere get more? What, exactly, is going on at the poles (Is it light there? Dark there? Same or different at the N and S poles?) (It might help to rotate the ball through 360º and see what fraction of the time the tack is in the light.)

Rotate the ball so that the tack is back at noon position. Note the length of the shadow it casts. This does not have to be quantitative – just note how the shadow gets longer or shorter depending on the position of the tack with respect to the bulb.

Everyone move 1/4 the way around the “Sun” counterclockwise. Make sure you and the axis keep pointing in the same direction relative to the room (i.e. don't keep facing the “Sun”!). Rotate “Earth” through one day.

Q4. What season is it (in the Northern Hemisphere)? What do you notice about the total hours of sunlight at the North Pole? At the South Pole?

Q5. Comment on the relative amounts of light each hemisphere receives over the course of one day at this point in Earth's orbit. Are they the same or does one hemisphere get more?

This point in Earth's orbit is a solstice—the longest day of the year in the Northern Hemisphere and the shortest in the Southern. Rotate Earth so the tack is at the noon position. Note the shadow it casts. Is it longer or shorter that at the equinox? (Again, you don’t have to answer this question in writing at this point, but will have to later – Q11 and the text leading up to it.)

Move 1/4 around the orbit once again. As before, rotate the Earth through one day.

Q6. What season is it now? Comment on the relative amounts of light each hemisphere receives over the course of one day. Are they the same or does one hemisphere get more? What is happening at each of the poles?

With the tack at noon position, note the length of the shadow.

Q7. How does the noontime shadow length compare with the previous two positions?

Finally, move another 1/4 of the way around the “Sun” counterclockwise. Rotate the Earth through one day.

Q8. What season is it now? What do you notice about hours of sunlight at the North Pole and the South Pole?

Q9. Comment on the relative amounts of light each hemisphere receives over the course of one day at this solstice. Are they the same or does one hemisphere get more?

Q10. At noon position, how does the length of the shadow compare to the equinoxes and to the Summer Solstice?

What if the tilt of Earth's axis relative to the orbital plane were different? Orient your ball so that the axis is vertical.

Q11. As you walk around one orbit, how does the amount of light received by each hemisphere differ from when the axis was tilted?

The rest of the lab is done at your tables.

Altitude of the Sun and the change of Seasons

Think for a moment about the length of the noontime shadows cast by the tack at the four points in the orbit from the previous activity.

Q12. From your experience in the real world, how do shadow lengths depend on the height of the Sun in the sky? Based on your answer, how does the maximum altitude of the Sun at noon change with the seasons?

You now will use the SkyGazer planetarium software to explore how the Sun's motion through the sky changes through the year and with your location on the Earth. (This is the same software that is packaged with your textbook (if you bought a *new* copy), so you can continue to explore outside of lab!) For this activity, we suggest you start with the following settings:

- Chart Menu - Set Location
    - Choose "Philadelphia" or "Sproul Observatory" from the list (Do *not* enter it manually)
- Display Menu – Sky & Horizon
    - Select "Translucent" (so you can see below the horizon)

- Display Menu – Reference Markers
  - Check all (might have to first check "display reference markers") except "ecliptic," "solstice," and "equinox."
- Display Menu – Natural Sky and Coordinate Grids
  - Uncheck all (though you might prefer having "Natural Sky" on)

Click and hold the left mouse button to move the view so that you are looking Due South (directly south; azimuth = 180º). The view on screen is what you would see if you were standing outside facing South. Remember, when facing South, East is to your left, West is to the right, and North is behind you.

Under the Chart menu, set Time to Mar 21 2014, 12:00 p.m. Uncheck the box for Daylight Savings Time. Notice the Sun is just to the East of the meridian. (Apparent solar time is not equal to standard time). Change the standard time so that sun is on meridian by clicking on the minute hand of the clock and dragging it.

In your lab notebook make a table of dates in one column and maximum altitude of the Sun in another (you'll have a total of four entries). Click on the Sun. An Information box should pop up. Under "General" information, find and record the Altitude to the *nearest degree*. Repeat this procedure for June 21, September 21, and December 21.

Q13. Do your measurements support your earlier response for how shadow length depends on the altitude of the Sun? If not, explain why you need to revise your answer.

We can "visit" different latitudes easily via this software, either by entering a new latitude in the "Set Location" menu or by changing it in the "Location" box (the one with the map of Earth). Make a new table for maximum altitude of the Sun at the four dates above for at least the latitudes 90º N, 0º, 40º S, and 90º S.

Q14. In the Southern Hemisphere, what direction must you face to see the Sun at noon?

Q15. In what locations, if any, was the Sun directly overhead? On what dates?

Q16. You have a friend who insists that the Sun is always directly overhead at noon. Why is he or she wrong?

Length of Day

Return to Philadelphia (*make sure to choose it from the pull-down menu*; typing in the name will not actually change the location), and set the time to March 21, 2014 6:00 AM. "Face" the eastern horizon, and adjust the time so that the Sun is on the horizon (Altitude = 0º). Now you will look at how and why the length of the day changes with the seasons. Start by making yet another table in your notebook that looks like this:

Date	Time of Sunrise	Direction of Sunrise	Time of Sunset	Direction of Sunset	Length of Day
March 21					
June 21					
Sept. 21					
Dec. 21					

Record the direction of sunrise and sunset as an azimuth angle, and make sure you understand how that translates to a direction (E, ESE, NW, etc.).

Q17. What fraction of the tack's path as you rotate the ball is in the light and what fraction of the path does the tack spend in the dark? Are your measurements of length of day consistent with your observations with the styrofoam ball? If not, explain the discrepancy.

Just for fun, let's go to the North Pole on the Summer Solstice. You don't need to record any measurements, but observe the Sun's position over the course of 24 hours. **Describe in your notebook what you see.**

Conclude tonight's notebook entry by using your observations with the styrofoam ball and with the software to answer the following questions:

Q18. Explain why there are more hours of daylight in the summer than in the winter. What is it about the Sun's path across the sky that makes this so? For full credit, refer to some specific observations and/or measurements you made in the lab (in addition to the interval between the Sun's rising and setting times in your table).

Q19. Why is it hotter in the summer than in the winter? There are two reasons.

Q20. How would the seasons be different if Earth's axis were not tilted?

Q21. What if the axis tilt were 90º?

To Hand In:

Write an introduction and a conclusion, as usual, and make sure to answer all the numbered questions (and make any tables you're instructed to) in the body of the lab write up.