Name: ASTR110L
Partner(s):

5 - Seasons

Purpose: To measure the distance of the Earth from the Sun over one year and to use the celestial sphere to understand the cause of the seasons. Answer all questions (Q1–Q47) here.
Due: in a week, at class time.

Pre-lab Questions—What do you think?:

Figure 1 shows two pictures of the Sun taken six months apart with the same camera, at the same time of the day, from the same location.

Q1) Are the images of the Sun the same size?

Q2) If they are not the same size, how can you explain the difference?

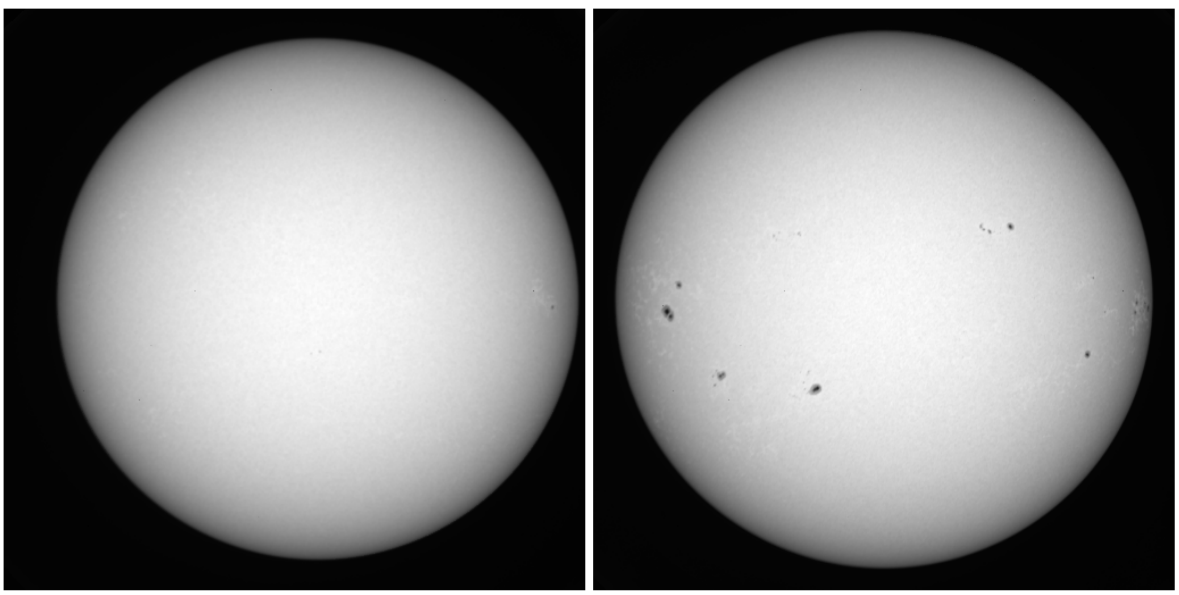


Figure 1: Pictures of the Sun taken six months apart from the Solar Dynamics Observatory, a satellite orbiting the Earth dedicated to studying the Sun.

Month: ____________________ **Month:** ____________________

Q3) Below each image, write the month when you think it was photographed. Briefly explain why.

Q4) What month or months of the year is your (northern hemisphere) weather warmest?

Plotting The Distance From The Earth To The Sun:

Materials:

- Metric ruler
- Calculator
- Solar image cross-sections (Chart 1)
- Circular graph paper (provided)

Procedure:

1. Figure 2 shows twelve images of the Sun taken over the course of a single year. Rectangular sections from the middle of these pictures have been cut out (see Figure 3) and are presented in Chart 1—Solar Image Cross-Sections.

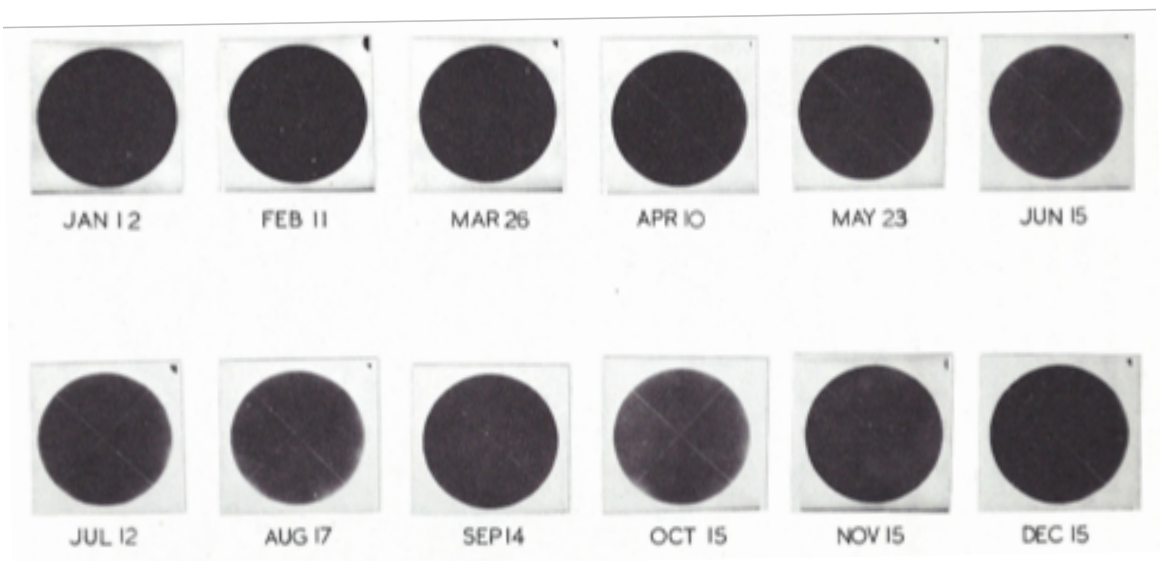


Figure 2: Solar images (negatives) taken between January 12 to December 15 in a single year. The dark circles represent the full disk of the Sun as seen from Earth.

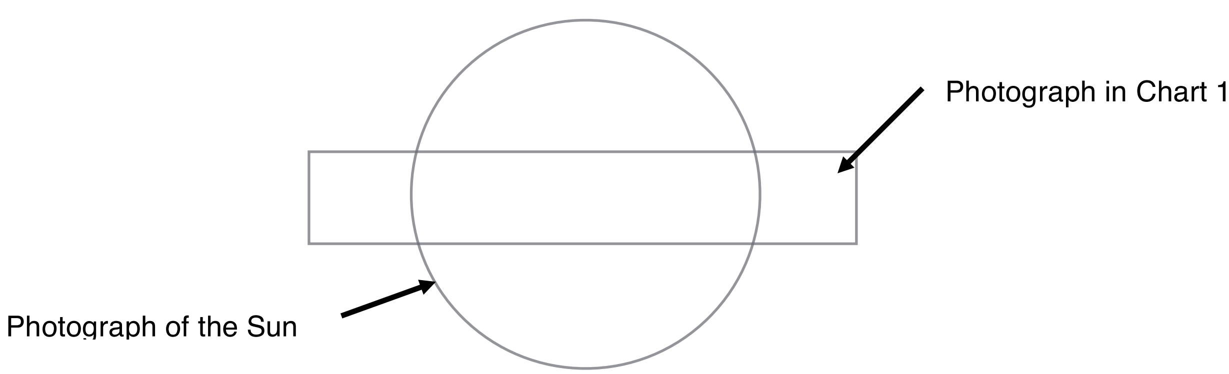


Figure 3: Layout of the images presented in Chart 1. Each image section comes from a larger image of the Sun (see Figure 1) but cut through the middle of the solar disk.

2. Measure the width of the Sun L to the nearest tenth of a centimeter (cm) using Chart 1. Record your measurements in the spaces to the right of each photo.

3. For the specific date each photograph was taken, calculate the distance d to the Sun in kilometers (km). You will do this by dividing 1,570,000,000 km cm (1.57×10^9 km cm) by the width L (in cm) of each solar photograph. Record the distance to the Sun corresponding to each measured diameter in the space in the column to the right of each photo. Use scientific notation (e.g. 1,000,000 = 10^6). Explicitly show what happens to the units.

Q5) Show one example calculation here.

5. Using the data on Chart 1, plot the position of the Earth for an entire year on the circular graph paper provided. The distance between the Sun and Earth is d in Chart 1. Because the dates of the photographs are not at the beginning of each month, be as accurate as possible by bisecting the wedges for each date on the graph.

6. Connect the points on the graph with a smooth curve. It is recommended to use a pencil first, then trace over this penciled curve with a pen.

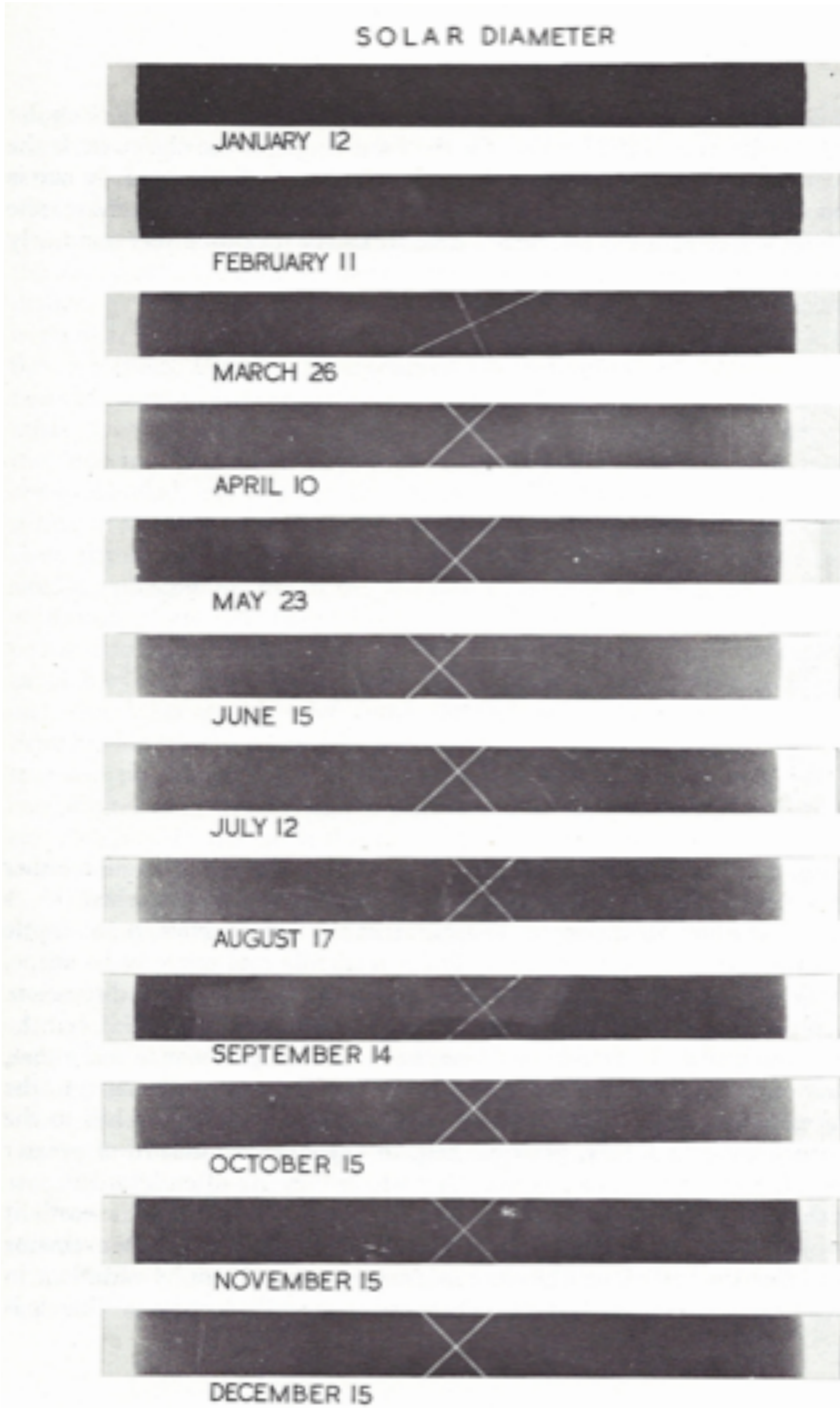
Q6) What does this curve represent?

Q7) In what month is the Earth farthest from the Sun?

Q8) In what month is the Earth closest to the Sun?

Q9) Compare the answers from the two previous questions to your predicted months in Figure 1 (Q3 and Q4). How are they the same or different?

Q10) Using your data and results obtained in this activity, describe what your graph shows (about 100 words).



L (cm)	*d (km)*

Chart 1—Solar Image Cross Sections: Plate IX from "The Paths Of The Planets" by R. A. R. Tricker, 1967

Q11) Discuss what conclusions you can draw from the observation that the Sun has a different apparent size in the northern-hemisphere summer than in its winter (about 100 words).

Q12) Discuss how the Earth-Sun distance relates to your (northern hemisphere) warmest and coldest months (about 100 words).

Modeling the Sun's Motion on the Celestial Sphere:

Materials:

Metric ruler	Hawaiian star compass
Protractor	Hemisphere from Lab 2: Solar Motion
Celestial sphere with accessories	Yellow dot stickers (Sun)

During this lab, we'll be only using constellations from this check list.

☐Cassiopeia	☐Gemini	☐Scorpio
☐Taurus	☐Leo	☐Sagittarius
☐Orion	☐Ursa Major (Big Dipper)	☐Cygnus
☐Canis Major	☐Crux (Southern Cross)	☐Pegasus

Procedure:

Position your celestial sphere and horizon collar to correspond to the latitude of Hilo (20° N). As an example, Figure 4 shows the side view of the celestial sphere at the Summer Solstice somewhere on Earth located at a latitude of 42° N, when the Sun is crossing the meridian. Set up the equipment for the latitude of Hilo before proceeding.

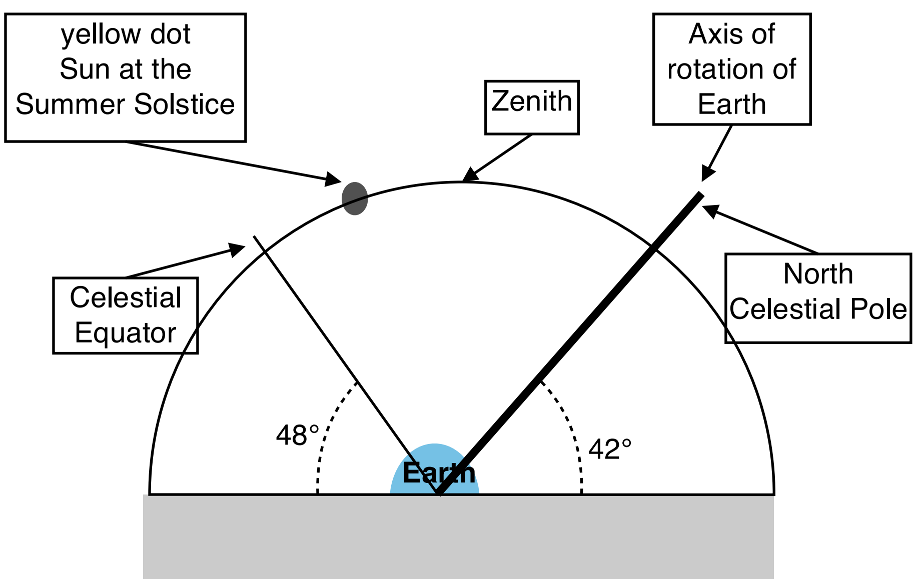


Figure 4: Celestial Sphere and horizon collar for a location on Earth (latitude: 42° N; longitude doesn't matter).

Be clear whether giving directions in *azimuth* as shown on the Hawaiian Compass (0° is due north; 90° is due east, 180° is due south, etc.) or relative to a cardinal direction (for example, "E by N" is 13.25° N of E).

When answering what constellation/asterism is where at what time, describe the position as specifically as possible, which includes the temporal as appropriate. Only use constellations traced on the celestial sphere.

Procedure/Data Collection—for Hilo:

1. Summer Solstice: On the celestial sphere, place the Sun on the ecliptic line for June 22 by moving your yellow dot. Move the celestial sphere to simulate sunrise. Sunrise is the moment when the upper edge of the Sun is at the horizon line. Next, rotate the celestial sphere from east to west until the Sun is on the western side of the horizon. This movement represents the apparent motion of the Sun from sunrise to sunset on June 22, the Summer Solstice in the northern hemisphere.

Q13) In what cardinal direction did the Sun rise? Be specific. ______________________

Q14) In what cardinal direction did the Sun set? Be specific. _______________________

Q15) Moving the Sun marker from sunrise to sunset, count the number of intervals that pass the western horizon, as accurately as possible. This number represents the hours of daylight. How many hours of daylight are there on June 22? _______________

Q16) Place the Sun at the meridian (noon). Noon is when the Sun is halfway between its rising and setting positions or at its highest point in the sky for that day. Fill out Figure 5 by referring to Figure 4. On this figure, draw the following:

- ❑ Axis of rotation of Earth: The rotation axis makes an angle equal to the latitude of Hilo with the horizon.
- ❑ Celestial Equator line: The Celestial Equator is 90° from the axis of rotation.
- ❑ Location of Sun with a circle: Hint: observe your celestial sphere on June 22.

On this figure, accurately label the angles between:

- ❑ Axis of rotation of Earth and horizon
- ❑ Celestial Equator and horizon

On this figure, label:

- ❑ Earth with an E
- ❑ horizon
- ❑ zenith with a Z
- ❑ Celestial Equator with CE
- ❑ axis of rotation of Earth with AR
- ❑ North Celestial Pole with NCP
- ❑ Sun with S

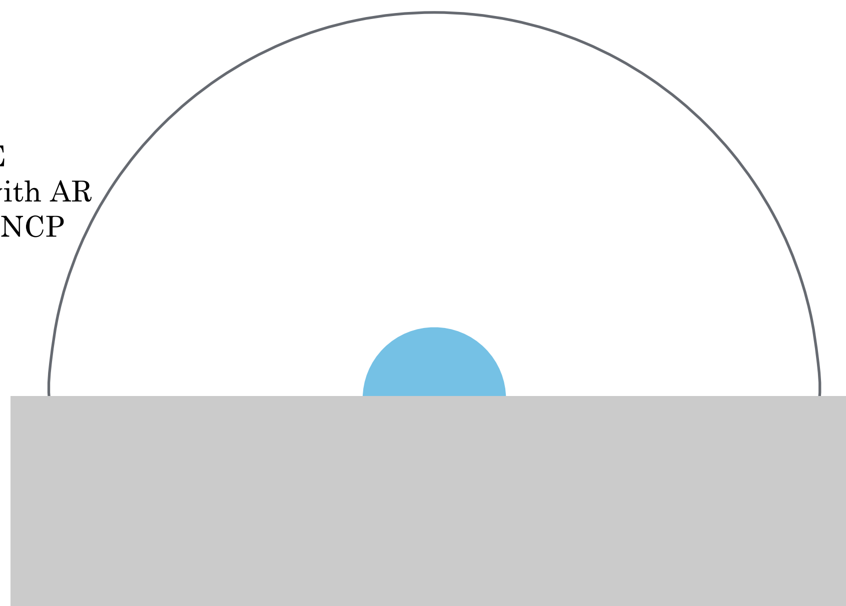


Figure 5

Q17) What pattern of stars will be close to zenith just after sunset?

Q18) What pattern of stars is close to zenith at 1 AM?

2. Autumn Equinox: On the Celestial Sphere, place the Sun on the ecliptic line for September 21 by moving your yellow dot. Move the celestial sphere to simulate sunrise. Next, rotate the celestial sphere from east to west until the Sun is on the western side of the horizon. This movement represents the apparent motion of the Sun from sunrise to sunset on September 21, the Autumn Equinox in the northern hemisphere.

Q19) In what cardinal direction did the Sun rise? Be specific. ______________________

Q20) In what cardinal direction did the Sun set? Be specific. _______________________

Q21) How many hours of daylight are there on September 21? Be as accurate as possible. _____________________

Q22) Place the Sun at the meridian (noon) and fill out Figure 6 in the same way as you filled out Figure 5. On this figure, draw the following:

- ❑ Axis of rotation of Earth: The rotation axis makes an angle equal to the latitude of Hilo with the horizon.
- ❑ Celestial Equator line: The Celestial Equator is 90° from the axis of rotation.
- ❑ Location of Sun with a circle: Hint: observe your celestial sphere on this date.

On this figure, accurately label the angles between:

- ❑ Axis of rotation of Earth and horizon
- ❑ Celestial Equator and horizon

On this figure, label:

- ❑ Earth with an E
- ❑ horizon
- ❑ zenith with a Z
- ❑ Celestial Equator with CE
- ❑ axis of rotation of Earth with AR
- ❑ North Celestial Pole with NCP
- ❑ Sun with S

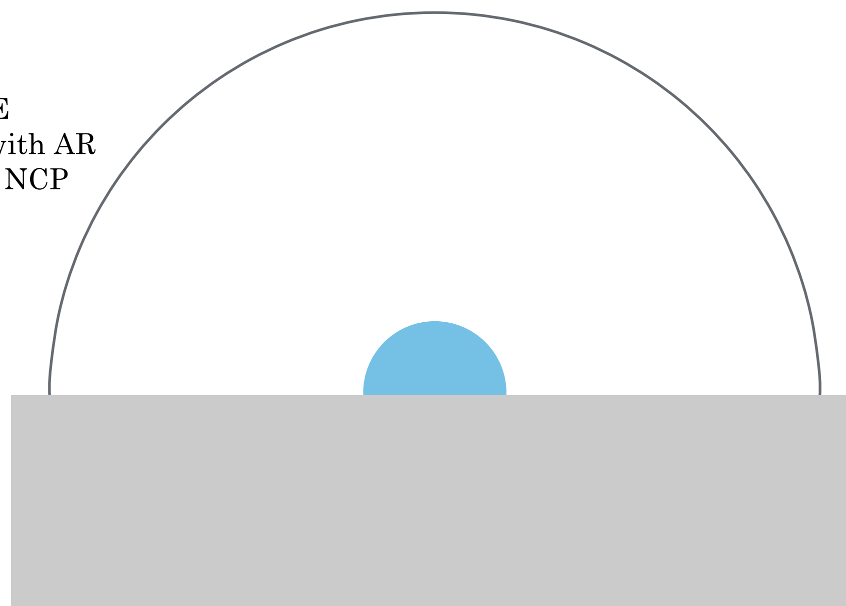


Figure 6

Q23) What constellations are visible close to the southern horizon just after sunset?

Q24) What is the location of Cygnus in the sky just after sunset? Be specific.

3. Winter Solstice: On the Celestial Sphere, place the Sun on the ecliptic line for December 21 by moving your yellow dot. Move the celestial sphere to simulate sunrise. Next, rotate the celestial sphere from east to west until the Sun is on the western side of the horizon. This movement represents the apparent motion of the Sun from sunrise to sunset on December 21, the Winter Solstice in the northern hemisphere.

Q25) In what cardinal direction did the Sun rise? Be specific. ______________________

Q26) In what cardinal direction did the Sun set? Be specific. _______________________

Q27) How many hours of daylight are there on December 21? Be as accurate as possible. _____________________

Q28) Place the Sun at the meridian (noon) and fill out Figure 7 in the same way as you filled out previous figures. On this figure, draw the following:

- ☐ Axis of rotation of Earth: The rotation axis makes an angle equal to the latitude of Hilo with the horizon.
- ☐ Celestial Equator line: The Celestial Equator is 90° from the axis of rotation.
- ☐ Location of Sun with a circle: Hint: observe your celestial sphere on this date.

On this figure, accurately label the angles between:

- ☐ Axis of rotation of Earth and horizon
- ☐ Celestial Equator and horizon

On this figure, label:

- ☐ Earth with an E
- ☐ horizon
- ☐ zenith with a Z
- ☐ Celestial Equator with CE
- ☐ axis of rotation of Earth with AR
- ☐ North Celestial Pole with NCP
- ☐ Sun with S

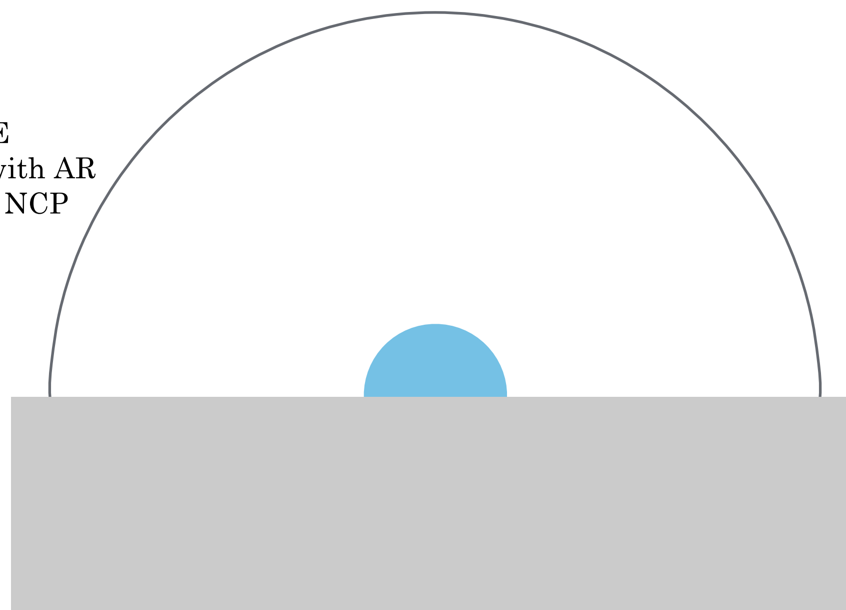


Figure ***7***

Q29) What constellations will be rising from the east just after sunset?

Q30) What constellation will just be setting in the northwest about 9 PM?

4. Spring or Vernal Equinox: On the Celestial Sphere, place the Sun on the ecliptic line for March 20 by moving your yellow dot. Move the celestial sphere to simulate sunrise. Next, rotate the celestial sphere from east to west until the Sun is on the western side of the horizon. This movement represents the apparent motion of the Sun from sunrise to sunset on March 20, the Vernal or Spring Equinox in the northern hemisphere.

Q31) In what cardinal direction did the Sun rise? Be specific. ______________________

Q32) In what cardinal direction did the Sun set? Be specific. _______________________

Q33) How many hours of daylight are there on March 20? Be as accurate as possible. _____________________

Q34) Place the Sun at the meridian (noon) and fill out Figure 8 in the same way as you filled out previous figures. On this figure, draw the following:

- ❑ Axis of rotation of Earth: The rotation axis makes an angle equal to the latitude of Hilo with the horizon.
- ❑ Celestial Equator line: The Celestial Equator is 90° from the axis of rotation.
- ❑ Location of Sun with a circle: Hint: observe your celestial sphere on this date.

On this figure, accurately label the angles between:

- ❑ Axis of rotation of Earth and horizon
- ❑ Celestial Equator and horizon

On this figure, label:

- ❑ Earth with an E
- ❑ horizon
- ❑ zenith with a Z
- ❑ Celestial Equator with CE
- ❑ axis of rotation of Earth with AR
- ❑ North Celestial Pole with NCP
- ❑ Sun with S

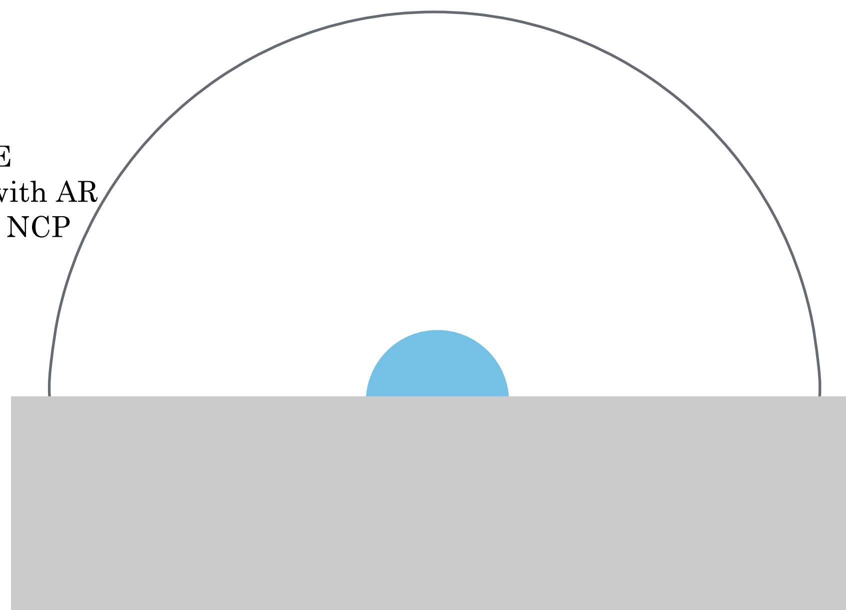


Figure 8

Q35) Describe the location of Orion in the sky just after sunset. Be specific.

Q36) What constellation is high in the southern sky at 9 PM?

Q37) Describe the location in the sky of the constellation Orion at sunset for the beginning of each season; be specific:

Summer: Winter:

Autumn: Spring:

Q38) Use the celestial sphere to predict how your actual sunrise and sunset would look for the next three months. Write down the cardinal directions of sunrise and sunset; be specific.

Month	**Sunrise Direction**	**Sunset Direction**

Discussion Questions:

Complete the following with your partner(s) or without, in the lab or out (but then be sure to turn it in next week). Before leaving the lab, check with the instructor or TA that you have all the necessary data/observations.

Q39) Reflecting on your data from the celestial-sphere modeling:
a) Does the Sun always rise exactly from the east?

b) List the directions of <u>sunrise</u> at the beginning of each season; be specific:

Summer: Winter:

Autumn: Spring:

Q40) Again, synthesizing the previous configurations of the celestial sphere:
a) Does the Sun always set exactly west?

b) List the directions of <u>sunset</u> at the beginning of each season; be specific:

Summer: Winter:

Autumn: Spring:

Q41) Describe how the direction of sunrise/sunset changed from the beginning of autumn to the beginning of winter.

Q42) Compare the results from this activity with the data you collected in Lab 2: Solar Motion on the plastic hemisphere. Discuss whether and how your observations (Lab 2) are consistent (or not) with the data (here) from your celestial-sphere model. Be clear about what you observed in Lab 2 (about 100 words).

Q43) How did the number of daylight hours change from (be specific):
a) Summer Solstice to the Autumnal Equinox?

b) Autumnal Equinox to the Winter Solstice?

c) Winter Solstice to the Spring Equinox?

d) Vernal Equinox to the Summer Solstice?

Q44) How much is the difference between the number of hours for the day with the longest period of daylight and the day with the shortest period of daylight?

Q45) Describe the changes in the noon position of the Sun from (be specific):
a) Summer Solstice to the Autumnal Equinox?

b) Autumnal Equinox to the Winter Solstice?

c) Winter Solstice to the Spring Equinox?

d) Vernal Equinox to the Summer Solstice?

Q46) Thinking critically, is the Sun ever directly overhead at noon in Hilo? Why or why not? If yes, when?

Q47) Reflecting on this whole (long) lab:
a) Discuss how changes in the Earth-Sun distance and changes in the angle of the Sun above the horizon affect the seasons (at least 100 words).

b) Discuss whether the Earth-Sun distance or the angle of the Sun in the sky has a greater effect on the seasons (about 100 words).