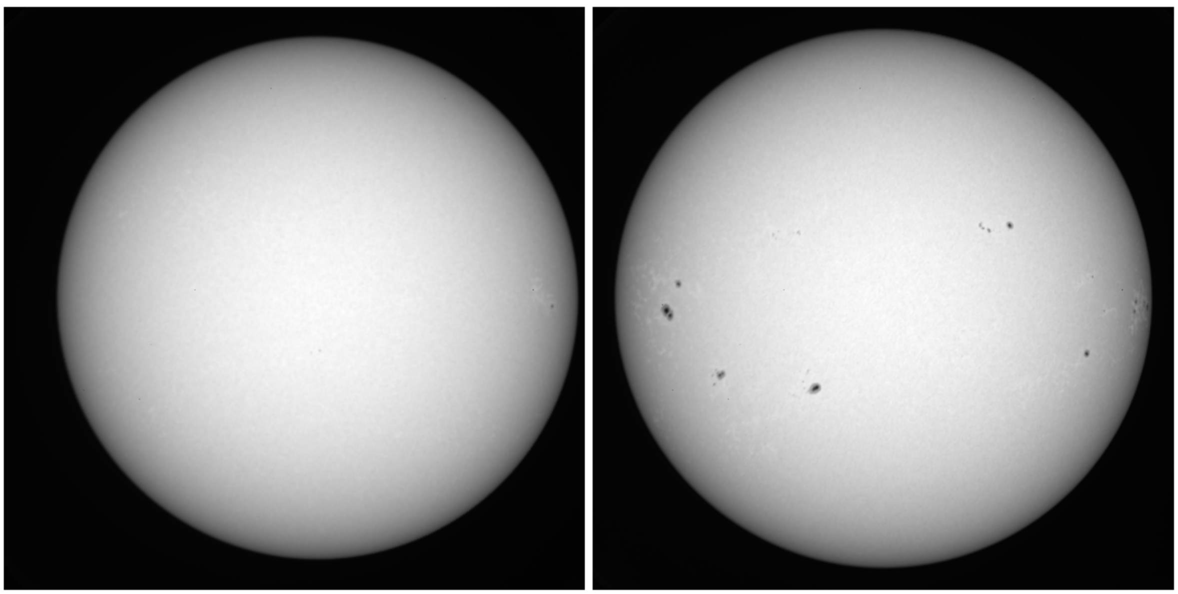
5 - Seasons

<u>Purpose</u>: To plot the distance of the Earth from the Sun over one year and to use the celestial sphere to understand the cause of the seasons.

What do you think?

Write answers to questions in the spaces provided.

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.



Month: ______________________ **Month:** ______________________

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.*

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

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

Q3. <u>Below</u> each image write the month in which you think it was photographed.

Q4. What month or months of the year is your weather warmest?

Plotting The Distance From The Earth To The Sun

Materials

- Metric ruler
- Calculator
- Solar image cross-sections (Chart 1)
- Graph paper (Provided on Page 5)

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 (refer to Figure 3) and are presented in Chart 1: Solar Image Cross-Sections.

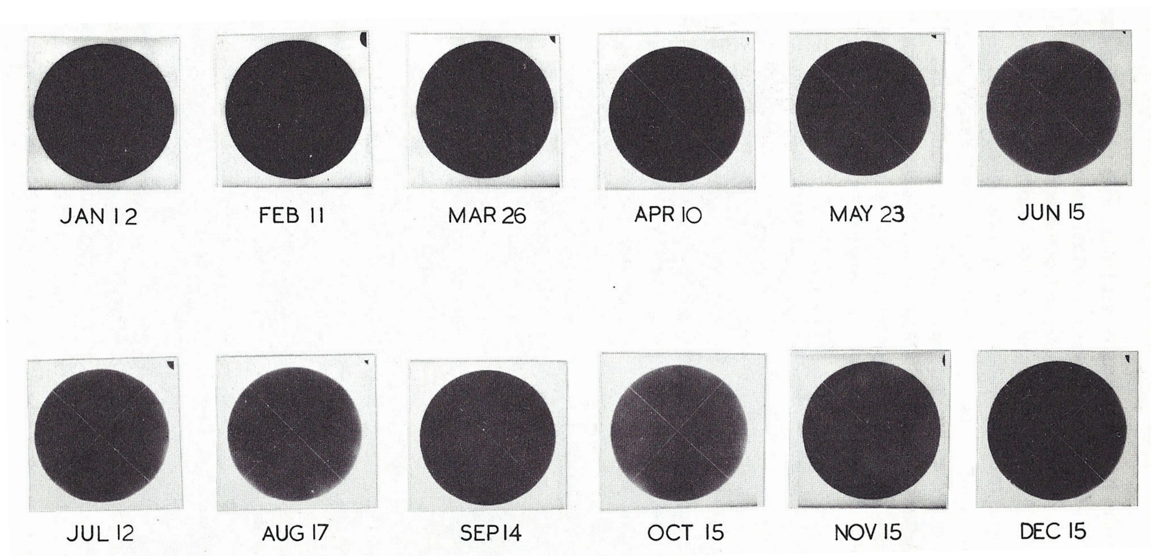


Figure 2: *Solar images (negatives) taken between January 12 to December 15 in a single year. The dark circles represent the full disk of the Sun as seen from Earth.*

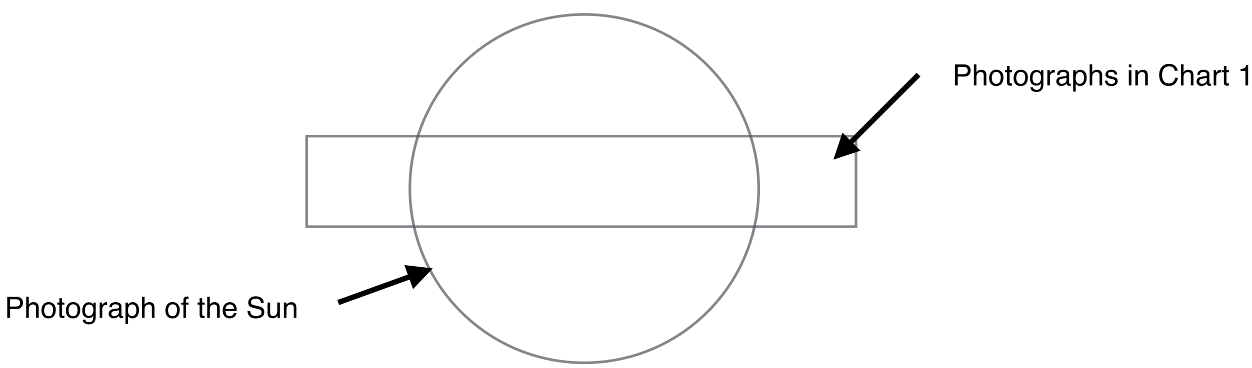
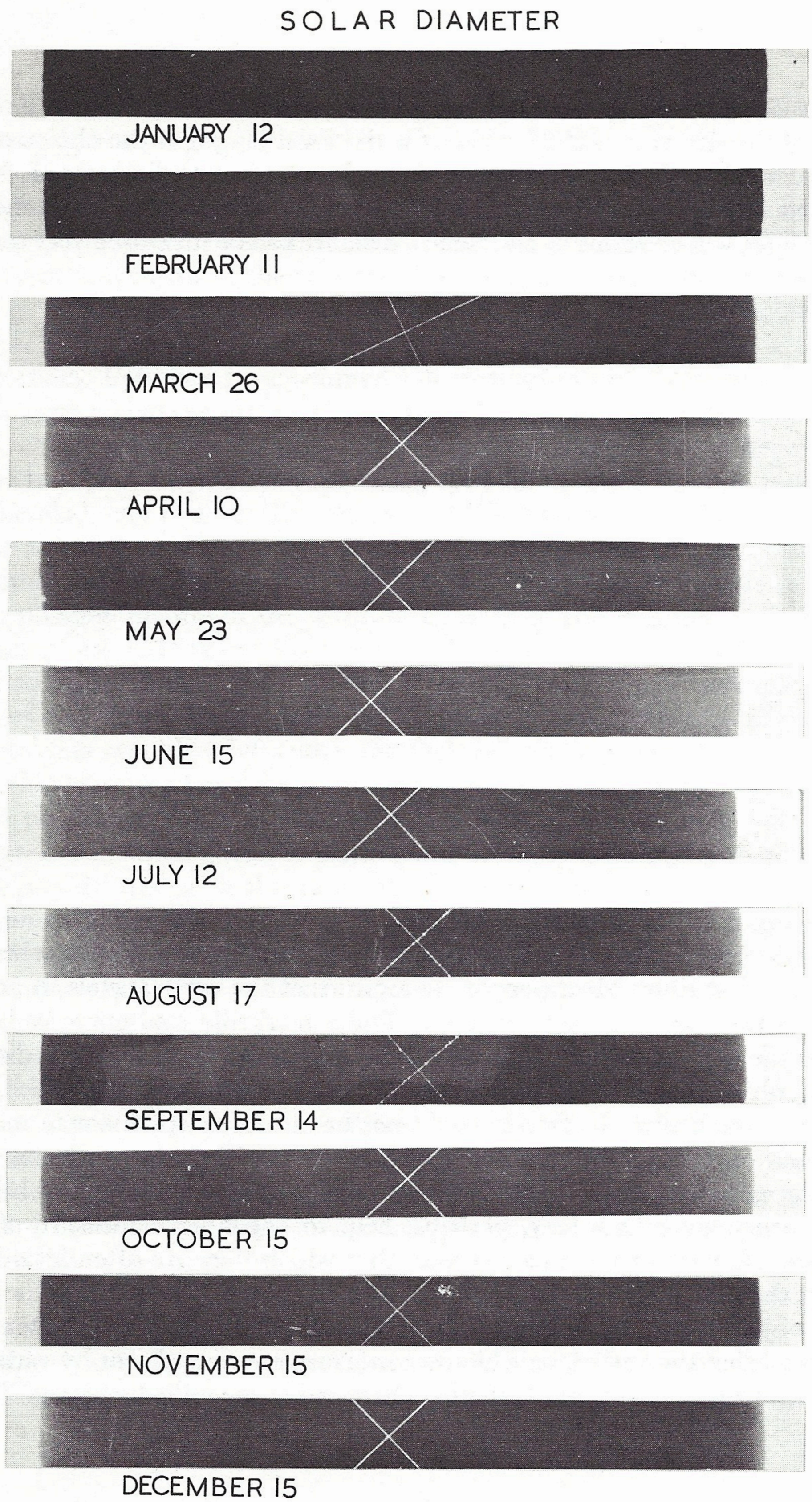


Figure 3: *Layout of the images presented in Chart 1. Each image section comes from a larger image of the Sun but cut through the middle of the solar disk.*



L (cm)	*d (km)*

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

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 left 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 1,500,000,000 km cm (1.5×10^9 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).

5. Using the data on Table 1, plot the position of the Earth for an entire year on the circular graph paper. The distance between the Sun and Earth is d in Table 1. Because the dates of the photographs are not at the beginning of each month, you will have to estimate to the best of your abilities the position for each date on the graph.

6. Connect the points on the graph with a smooth curve. Use a pencil first, then trace over this penciled curve with a permanent pen.

Q5. What does this curve represent?

Q6. In what month is the Earth farthest from the Sun?

Q7. In what month is the Earth closest to the Sun?

Q8. Compare the answers from the two previous questions to your predicted months in Figure 1. How are they the same or different?

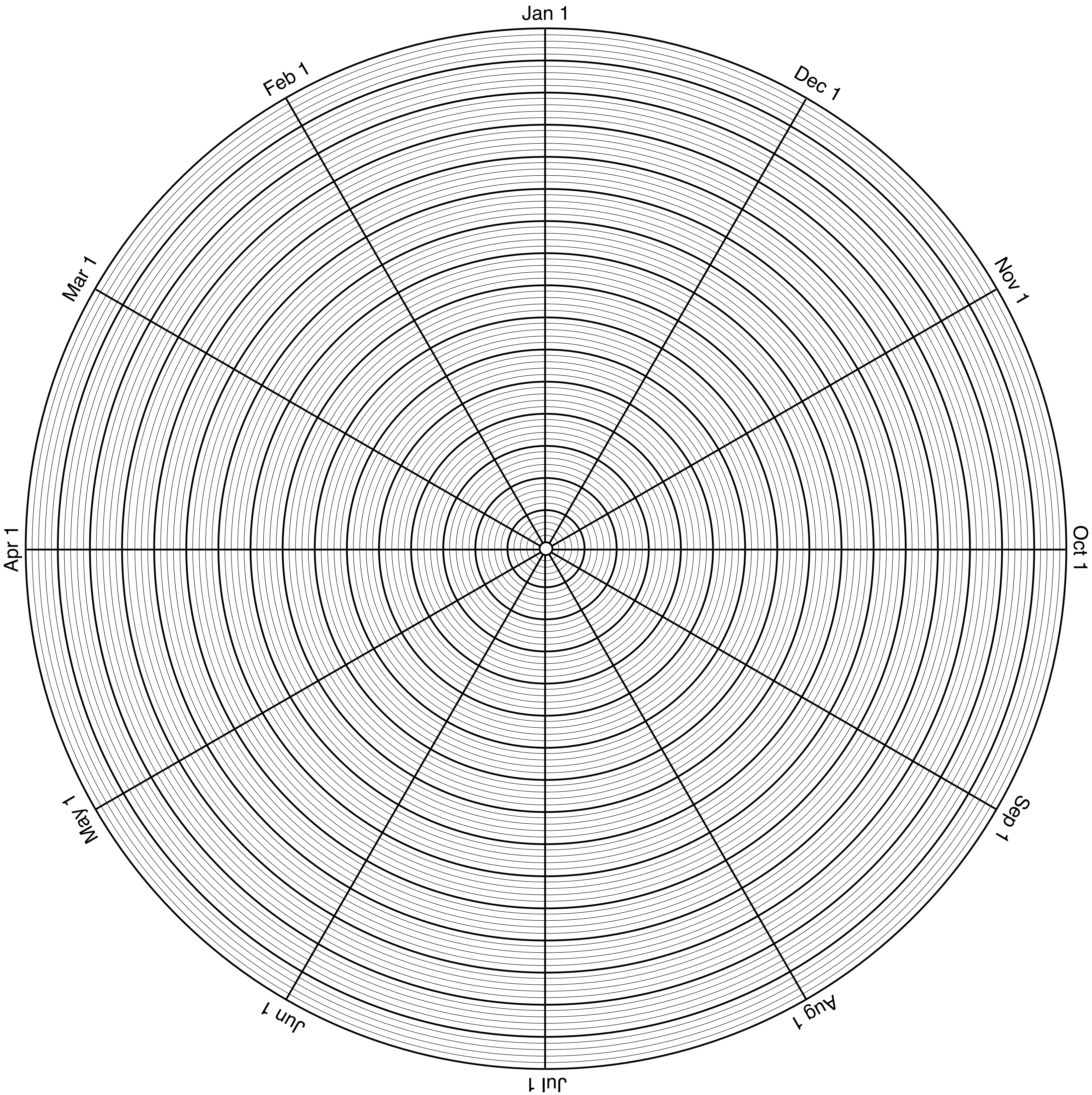
On a separate sheet of paper, answer questions Q9 through Q11.

Q9. Using your data and results obtained in this activity, describe what your graph shows. (About 100 words)

Q10. What conclusions can you draw from the observation that the Sun has a different apparent size in the Summer than in the Winter? (About 100 words)

Q11. Compare the months of your warmest weather to the month when the Earth is closest to the Sun. (About 100 words)

The heavy printed circles are separated by 10 million kilometers. The lighter circles are spaced 2 million kilometers apart.



Modeling the Sun's Motion On The Celestial Sphere

Materials

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

Procedure

Position your celestial sphere and horizon collar to correspond to the latitude of Hilo (20° latitude). 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° North** when the Sun is crossing the meridian.

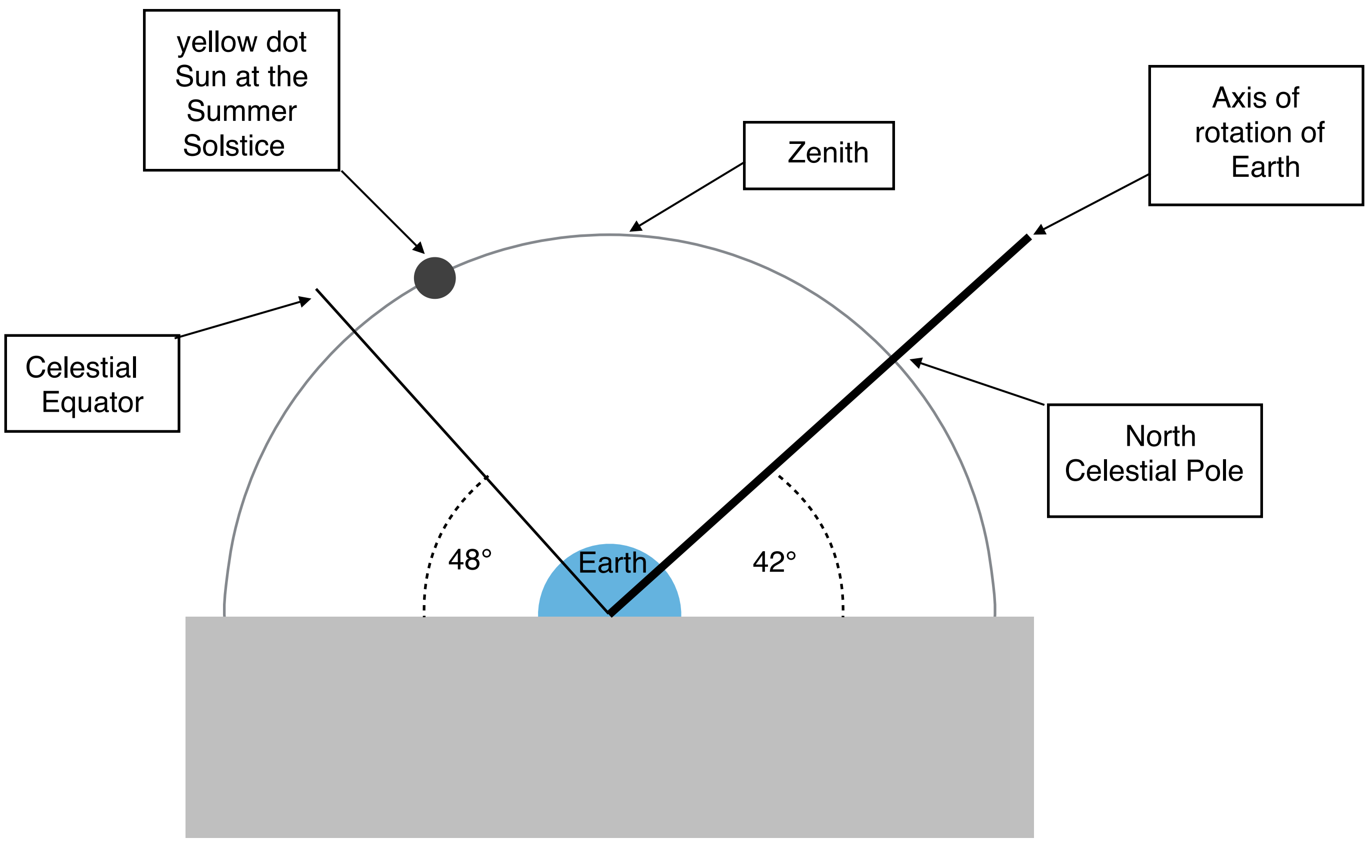


Figure 4: *Celestial Sphere and horizon collar for a location on Earth at a latitude of 42° North. NB that the longitude does not matter.*

Set up the equipment for the latitude of Hilo before proceeding.

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.

Q12. In what cardinal direction did the Sun rise? ______________________________

Q13. In what cardinal direction did the Sun set? ______________________________

Q14. Moving the Sun marker from sunrise to sunset, count the number of intervals that pass the western horizon. This number represents the hours of daylight. How many hours of daylight are there on June 22?

____

Q15. 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 Fig. 5 by referring to Fig. 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: To find its location observe your celestial sphere on June 22.

On this figure, write down the angles between:

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

On this figure, label:

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

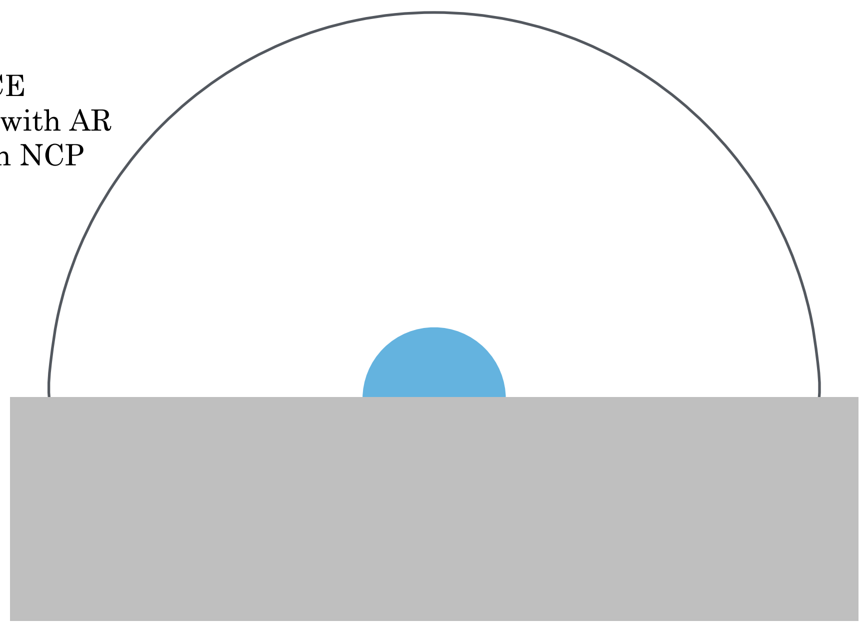


Figure 5

Q16. What pattern of stars will be close to zenith just after sunset? ______________

Q17. What pattern of stars is close to zenith at 1am? ______________________________

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.

Q18. In what cardinal direction did the Sun rise? ______________________________

Q19. In what cardinal direction did the Sun set? ______________________________

Q20. How many hours of daylight are there on September 21? ____________________

Q21. Place the Sun at the meridian (noon) and fill out Fig. 6 in the same way as you filled out Fig. 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: To find its location observe your celestial sphere on this date.

On this figure, write down the angles between:

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

On this figure, label:

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

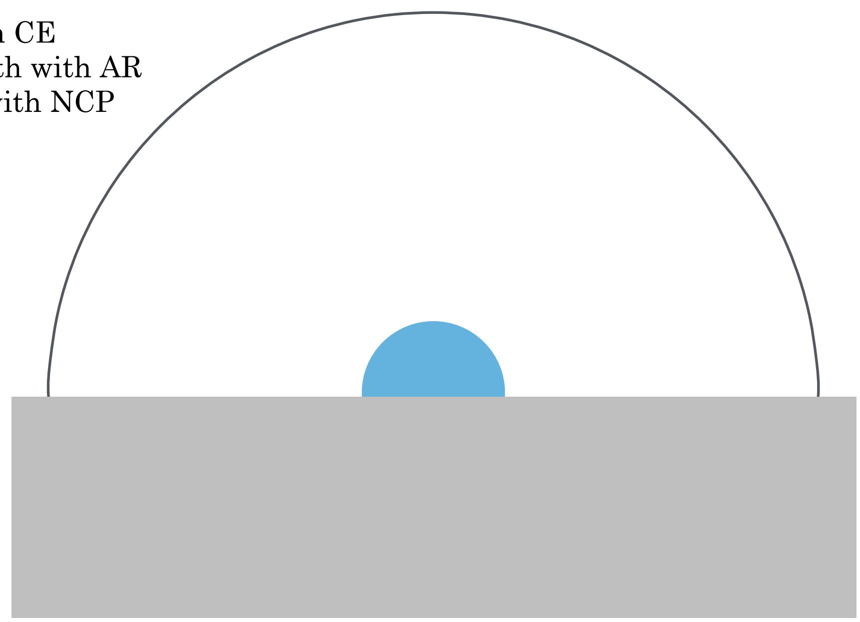


Figure 6

Q21. What constellations are visible close to the southern horizon just after sunset?

Q22. What is the location of Cygnus in the sky just after sunset? _________________

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.

Q23. In what cardinal direction did the Sun rise? ______________________________

Q24. In what cardinal direction did the Sun set? ______________________________

Q25. How many hours of daylight are there on December 21? ____________________

Q26. Place the Sun at the meridian (noon) and fill out Fig. 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: To find its location observe your celestial sphere on this date.

On this figure, write down the angles between:
- ☐ Axis of rotation of Earth and horizon
- ☐ Celestial Equator and horizon

On this figure, label:
- ☐ the Earth with an E
- ☐ the horizon
- ☐ the zenith with a Z
- ☐ the Celestial Equator with CE
- ☐ the axis of rotation of Earth with AR
- ☐ the North Celestial Pole with NCP
- ☐ the Sun with S

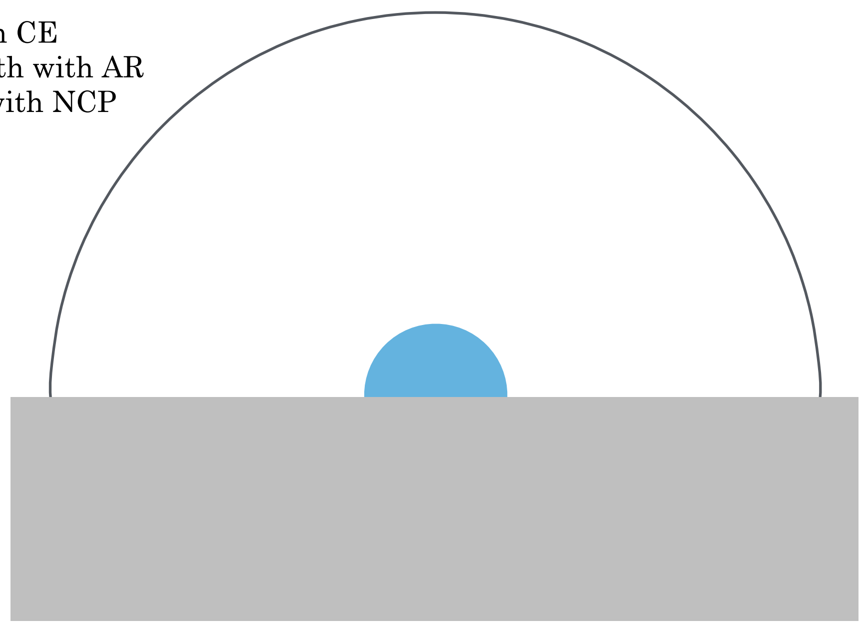


Figure 7

Q28. What constellations will be rising from the east just after sunset?

Q29. What constellation will just be setting in the northwest about 9pm?

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.

   Q23. In what cardinal direction did the Sun rise? ______________________________

   Q24. In what cardinal direction did the Sun set? ______________________________

   Q25. How many hours of daylight are there on March 20? ____________________

   Q26. Place the Sun at the meridian (noon) and fill out Fig. 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: To find its location observe your celestial sphere on this date.

   On this figure, write down the angles between:
   - ☐ Axis of rotation of Earth and horizon
   - ☐ Celestial Equator and horizon

   On this figure, label:
   - ☐ the Earth with an E
   - ☐ the horizon
   - ☐ the zenith with a Z
   - ☐ the Celestial Equator with CE
   - ☐ the axis of rotation of Earth with AR
   - ☐ the North Celestial Pole with NCP
   - ☐ the Sun with S

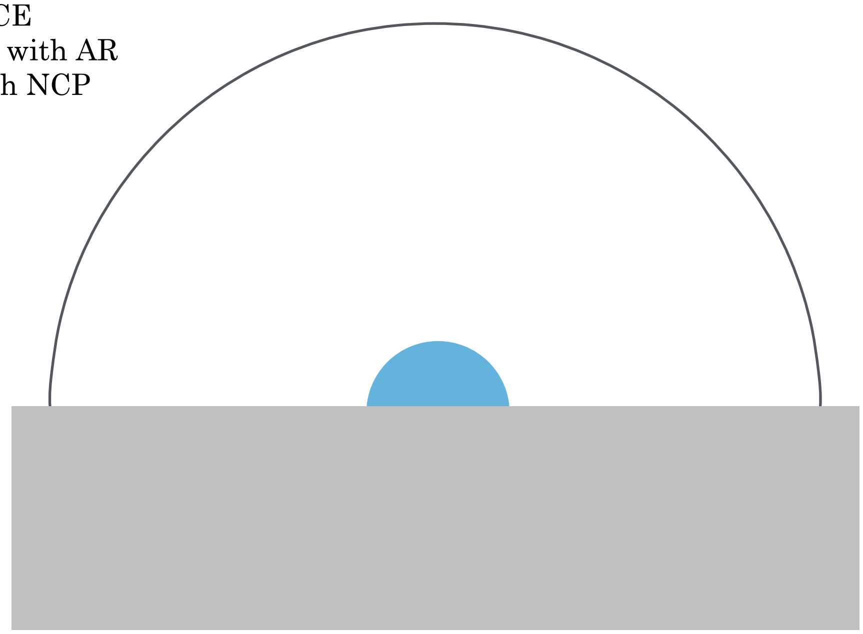


Figure 8

   Q34. Describe the location of Orion in the sky just after sunset.

   Q35. What constellation is high in the southern sky at 9pm?

Discussion Questions:

Write your answers in the spaces below.

Q36.

a) Does the Sun always rise exactly from the east?

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

Summer: Winter:

Autumn: Spring:

Q37.

a) Does the Sun always set exactly west?

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

Summer: Winter:

Autumn: Spring:

Q38. Compare the results from this activity with the data you collected in Lab 2: Solar Motion on the plastic hemisphere.

a) Were your observations consistent with the data from your Celestial Sphere model?

b) Describe how the direction of sunrise/sunset changed from the beginning of Autumn to the beginning of Winter.

c) Use the Celestial Sphere to predict how your actual sunrise/sunset would look for the next three months. Write down the cardinal directions of sunrise and sunset.

Q39. How did the number of daylight hours change from the:

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?

Q40. What 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?

Q41. Describe the changes in the noon position of the Sun from:

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?

Q42. Was the Sun ever directly overhead at noon in Hilo? If so, when?

Q43.

a) Discuss how changes in the distance of the Earth from the Sun and changes in the angle of the Sun above the horizon affect the seasons.

b) Which of these has a greater effect? Explain.

Q44. Describe the location in the sky of the constellation Orion at sunset for the beginning of each season:

Summer:

Winter:

Autumn:

Spring: