

### 3 - Celestial Sphere

Purpose: To construct and use a celestial sphere to show the motion of the Sun and stars in the sky. There are six questions, Q1–Q6, to answer on a separate piece of paper.

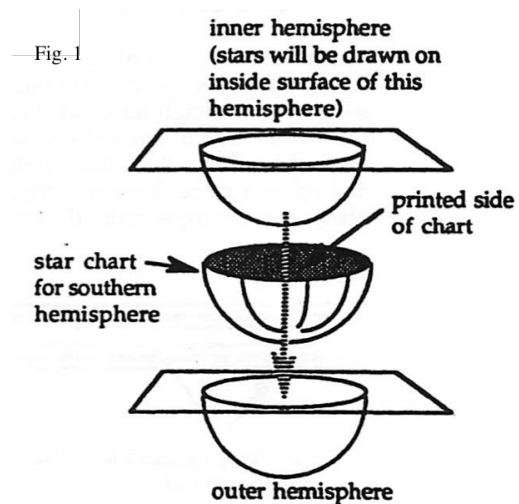
Due: in a week, at the start of class

Materials:

- |                                    |                                  |
|------------------------------------|----------------------------------|
| 2 plastic hemispheres              | small Earth globe                |
| wood mount for celestial sphere    | protractor                       |
| star chart sheets: north and south | scissors                         |
| blocks (adjust height)             | binder clips, tape               |
| transparent ecliptic strip sheet   | yellow dot sticker               |
| paper horizon collar               | pens (dry-erase or transparency) |
| metal rod                          | ruler                            |
| paper clips                        | Hawaiian Star Compass            |

#### Procedure A—Assembling Celestial Sphere:

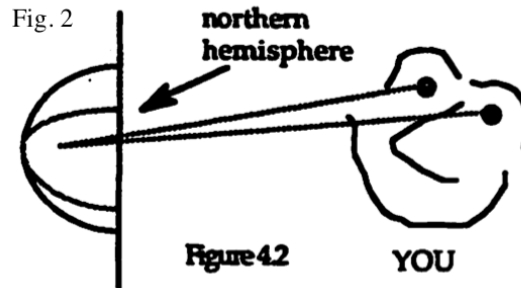
1. If you were given uncut star charts, cut out the two star charts with the scissors. Cut along the outside lines only. The star charts will look like flowers with eight petals.
2. Place the chart of the southern sky on the outside of a plastic hemisphere with the printed side facing down (see Figure 1). Align the center of the star chart with the center of the hemisphere and secure it with tape. Carefully align the chart so the ends of the ecliptic (the line that runs across the chart’s “petals”) touch the base of the hemisphere at two opposite ridges and lies flat against the hemisphere as much as possible. The ridges should coincide with the edges of the petals so that each quadrant of the hemisphere has two petals. Secure the chart by taping the chart down.  
Show your work to your instructor or teaching assistant (TA) before continuing to the next step.



3. Mark the stars on the inside of the hemisphere with the pen. Draw the lines that mark the ecliptic and the brighter constellations. The brighter stars are indicated by bigger symbols. (The “magnitude” of a star is an indication of its brightness. On this chart the brightest stars are 0<sup>th</sup> magnitude and the dimmest stars 4<sup>th</sup> magnitude.)
4. When you have marked all the stars, repeat steps 2–4 with the northern star chart and the other hemisphere. Confirm that the ecliptic lines touch the base at opposite ridges.

**Questions:**

Look into the opening (the concave side of the hemisphere) of the northern hemisphere (see Figure 2.) Discuss with your lab partners and write individual answers to questions on a separate sheet of paper with your and your partners' names.



**Q1)** What star is found in the center of the northern hemisphere?

**Q2)** What pattern of stars can be used to help you locate this star? Clearly explain how (words and/or figure). The instructor or TA can help you identify constellations.

The constellations with lines on the northern hemisphere are:

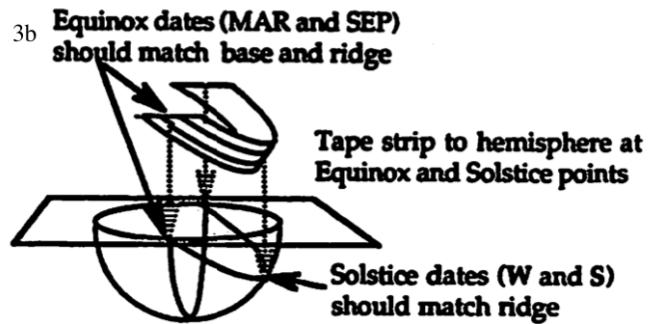
- \* Leo,
- \* Gemini,
- \* Taurus,
- \* Pegasus,
- \* Cassiopeia,
- \* Cygnus with the Summer/Fall Triangle
- \* Big Dipper (an asterism - an easy to recognize pattern, not a constellation), and
- \* northern half of Orion.

The constellations with lines on the southern hemisphere are:

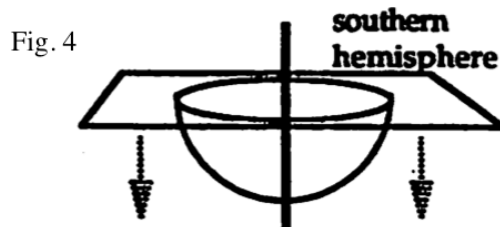
- \* Scorpius,
- \* Sagittarius,
- \* Canis Major,
- \* Southern Cross,
- \* southern half of Orion, and
- \* stars Alpha and Beta Centauri.

**Procedure A—Assembling Celestial Sphere (cont'd):**

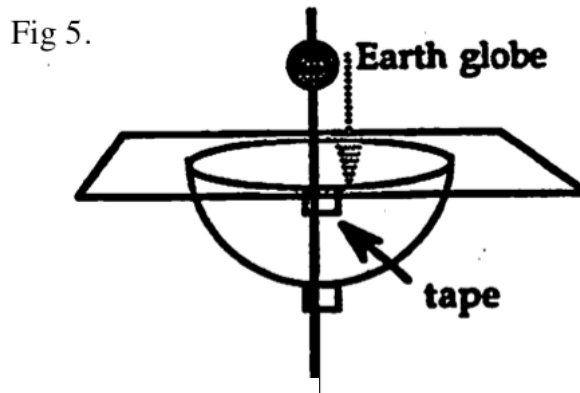
5. Cut out the two transparent strips of dates on the ecliptic chart (see Figure 3a). Tape the MAR to JUN to SEP strip onto the outside of the northern hemisphere (see Figure 3b). The ecliptic line on the hemisphere should pass through the center dates on the strip. The S mark in JUN should line up with the middle ridge of the northern hemisphere. Tape the SEP to DEC to MAR strip onto the southern hemisphere. The ecliptic line should run through the middle of the strip and the W in DEC should align on a ridge.



6. Push the metal rod through the hole in the northern hemisphere from the outside to the inside (see Figure 4). Wrap a piece of tape around the wire leaving about five inches outside the sphere. This tape will hold the northern hemisphere in place.

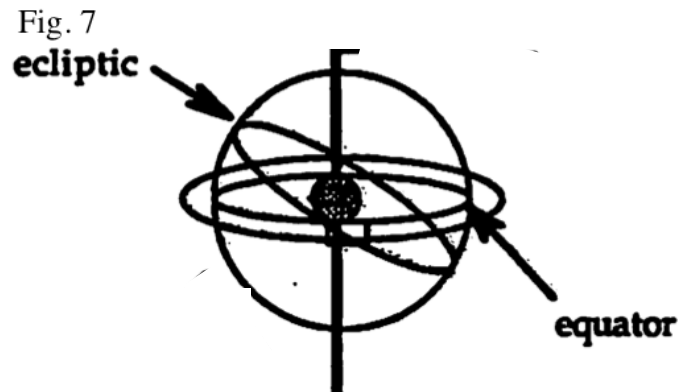
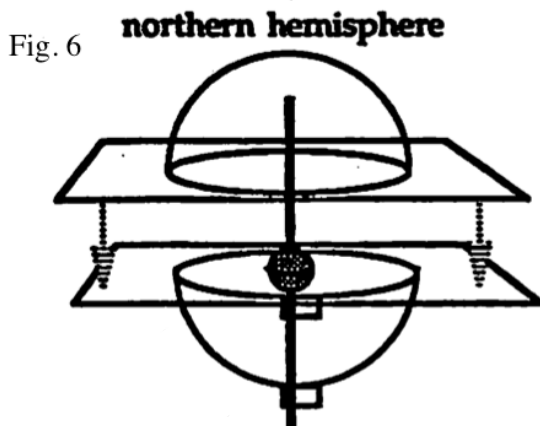


7. Gently slide the Earth globe onto the wire so the north pole faces the northern hemisphere. Line up Earth's equator with the flat base of the hemisphere using a ruler as a guide. Place a piece of tape on the wire under the Earth's north and south poles to hold the globe in place (see Figure 5).

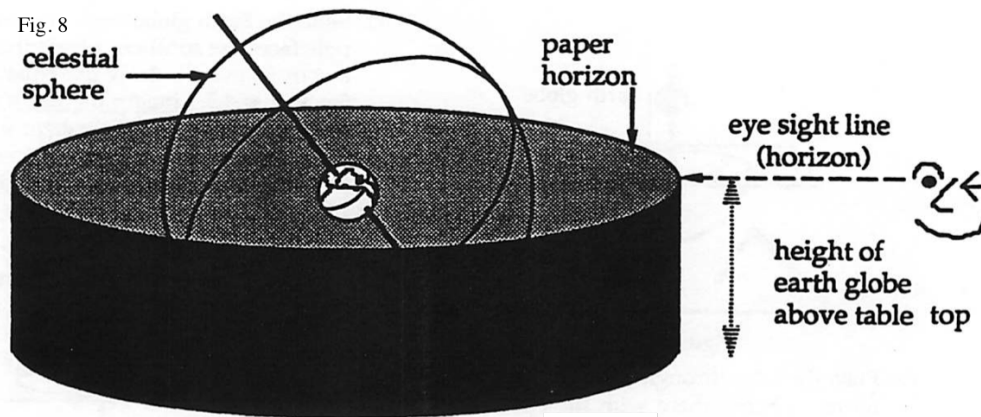


8. Push the wire through the celestial pole of the southern hemisphere so the openings of the two hemispheres face each other.

9. Rotate the hemisphere until the points where the ecliptic touches the equator align on both hemispheres. (The ecliptic should completely encircle the sphere and should pass both above and below the equator as shown in Figure 6.)
10. Use binder clips to clamp the edges of your two spheres together on the four corners.
11. Check: The clear plastic sphere should rotate freely on the wire; the Earth globe should be at the center of the sphere with north facing up; and the northern hemisphere should be on the upper half of the sphere (see Figure 7).



12. Gently push the wire into the wooden block. Measure the angle between the wire and the horizontal. It should be approximately the latitude of Hilo ( $19^{\circ}43'$ ), roughly  $20^{\circ}$ .
13. Place the paper horizon collar around your celestial sphere (see Figure 8). The top edge of the paper loop represents the horizon, the imaginary circle where the sky touches the Earth. The celestial sphere should sit completely inside the paper loop. Tighten the horizon around the sphere using paper clips.



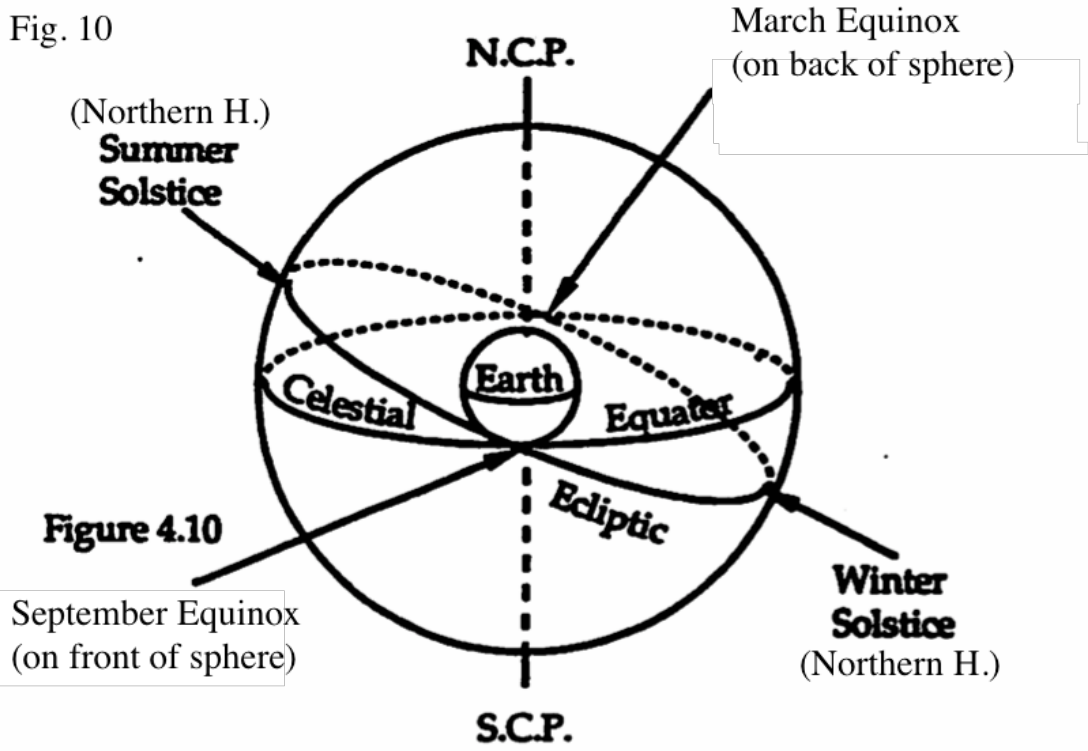
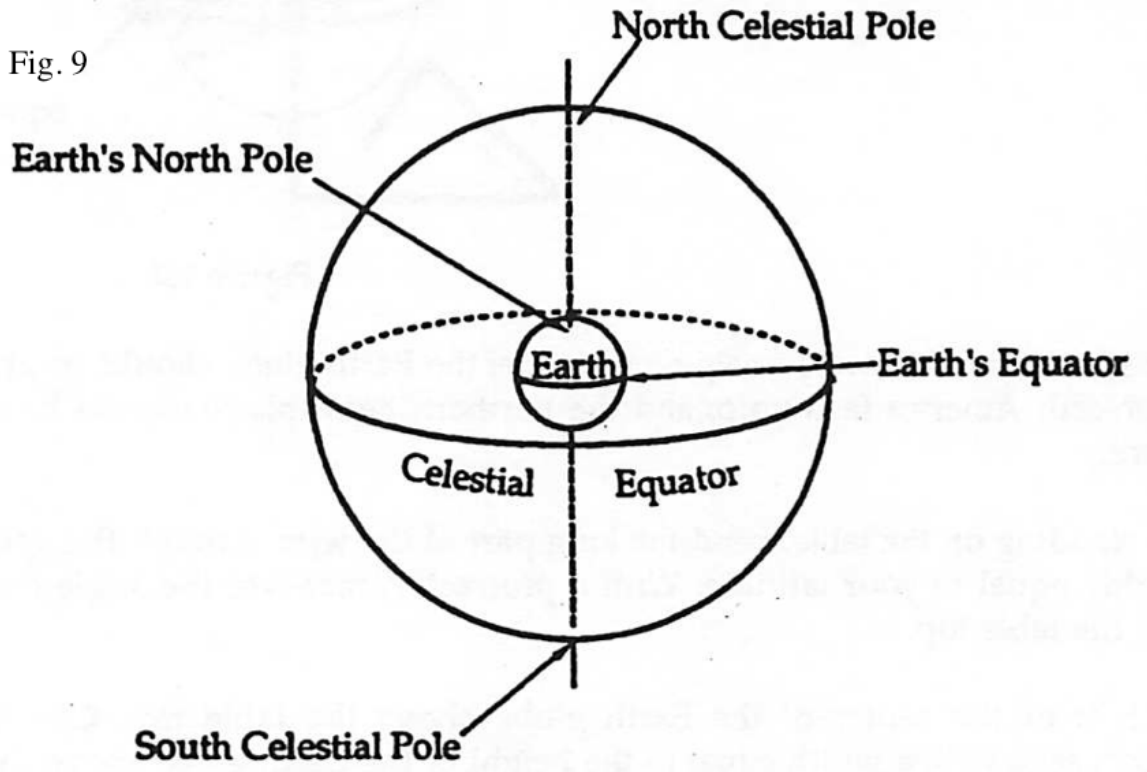
14. Use blocks or other objects to adjust the height of your wood base so that when your eyes are level with the top of the horizon collar, you see just half of Earth and the celestial sphere. The top edge of the collar, which represents the horizon, should be at the same height above the table as the center of the Earth globe. You can measure the height of the center of the Earth globe above the tabletop and make sure that it's the same as the height of the paper horizon loop.

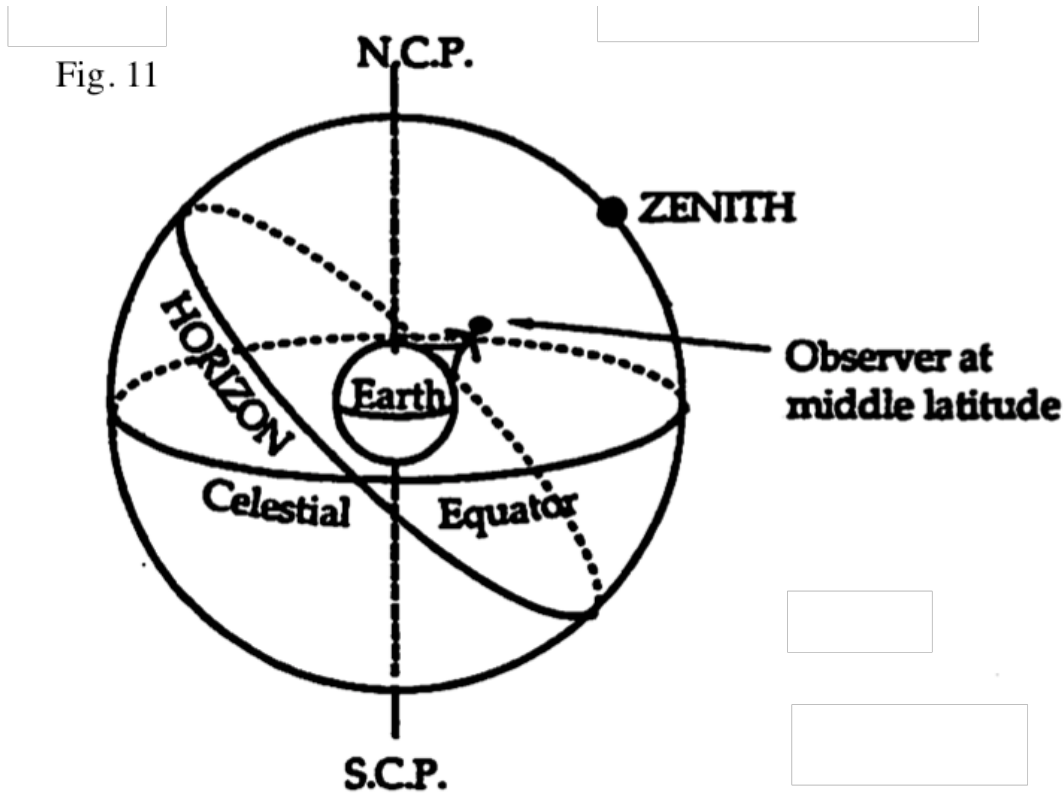
## Orientation on the Celestial Sphere:

The celestial sphere is a model you can use to describe, explain, and predict the motion of the Sun and the stars in the sky. It models how the sky looks from Earth. Identify the underlined concepts on your celestial sphere:

- 1) There are imaginary points such as the North and South Celestial Poles (NCP. and SCP) and imaginary lines such as the Celestial Equator (CE) positioned on this sphere. Earth is located at the sphere's center. Currently, the North Celestial Pole is very close to a star called Polaris.
- 2) The ecliptic is the apparent annual path of the Sun on the Celestial Sphere. Notice that the ecliptic is tilted relative to the celestial equator. As the Sun appears to move across the sky, it passes through a band of constellations known as the zodiac.
- 3) The points on the ecliptic that intersect with the celestial equator are called equinoxes. There is a March Equinox (also known as the North Crossing Equinox, since the Sun appears to move into the Northern Hemisphere in March, or the Vernal Equinox which means Spring Equinox for the Northern Hemisphere) and a September Equinox (also known as the South Crossing Equinox or Autumnal Equinox in the Northern Hemisphere).
- 4) The points on the ecliptic that are farthest from the celestial equator are called solstices. In the northern hemisphere, the June Solstice, when the Sun is in the northern hemisphere, is the Summer Solstice, and the December Solstice, when the Sun is in the southern hemisphere, is the Winter Solstice.
- 5) The point directly overhead of the observer is called the zenith. The horizon is located 90 degrees away from the observer's zenith in every direction. If the observer were standing on a flat desert plain or in a boat on a calm sea, the horizon would be the circle where they sky "meets" the land or water.

Take a look at Figures 9, 10, and 11. These are related to the celestial sphere you have just built in the following ways. The metal rod that passes through the globe is the vertical dashed straight line. The point where the wire comes out of the northern hemisphere is the North Celestial Pole; the point where the wire goes into the southern hemisphere is the South Celestial Pole. The Celestial Equator is where the two hemispheres are fastened. The horizon is the top edge of the paper collar. The ecliptic is the circle made of the arcs drawn on the inside of each hemisphere.





**Procedure B—Modeling the Sun’s Daily Motion:**

1. On the ecliptic, locate the date that you made the observation from last week. Mark this date with a yellow dot sticker, the “Sun.”
2. Place the Hawaiian Star Compass directly under the celestial sphere on the table. Center the Earth with the center of the Compass when you see the celestial sphere directly from the top.
3. Place the horizon collar around the celestial sphere. Using paper clips, place the cardinal directions labels (N, S, E, and W) correctly along the top rim of the horizon collar.
4. Look at the sphere along a horizontal line level with the top of the collar and the Earth. Turn the sphere on its axis until the Sun sticker is at the same level as the horizon collar. Depending on whether the Sun is on the eastern or western horizon, this represents sunrise or sunset for the date from last week’s activity. With your partner(s), decide how to place the yellow dot so that it represents sunrise on that date. Refer to Figure 8.
5. Slowly rotate the sphere from east to west (clockwise as viewed from above the north) and watch the motion of the Sun sticker. When the sticker is leveled with the top of the collar, it’s at the sunset position.

## Discussion Questions:

*Discuss the following questions with your group. Individually, write your answers on a separate sheet of paper, with your and your partners' names.*

**Q3)** The celestial sphere is a model of the sky. Turning the sphere on its axis represents Earth turning on its axis. One complete rotation of the sphere corresponds to 24 hours. How many hours does the passing of each notch on the hemisphere represent?

**Q4)** Turn the sphere to move the Sun sticker from sunrise to sunset.

- a) Count and record how many notches pass the western horizon for this simulated "day."
- b) About how many hours of daylight were there in that day? Transform the number of notches into hours.
- c) What fraction of a 24-hour day is represented by the turn you gave the sphere?
- d) Obtain the actual daylight period for the date you did last week's activity; the instructor or TA can help. How did the actual time compare with the celestial-sphere time?

**Q5)** Compare the path of the Sun as demonstrated with your celestial sphere (your model) to the path (sunrise, position at noon, sunset) you plotted on the hemisphere last week (your actual data). Clearly discuss how they are similar and how they are different (100 words).

**Q6)** Mark the Sun for today's date on the celestial sphere. Set the celestial sphere for two hours after sunset for today. Using only your celestial sphere, answer the following questions:

- a) Name a constellation in the southern sky. Describe where it is more specifically; include a temporal description.
- b) Name a constellation near zenith. If not exactly at zenith, describe its position relative to zenith.
- c) Describe the position of the Big Dipper in the sky as specifically as possible.
- d) Name a constellation that is just rising. As specifically as possible, describe the direction where it is rising.
- e) Name a constellation that is below the horizon and cannot be seen at this time. Describe its position as specifically as possible.