3 - Celestial Sphere

Purpose: To construct and use a Celestial Sphere to show the motion of the Sun and stars in the sky.

Materials:

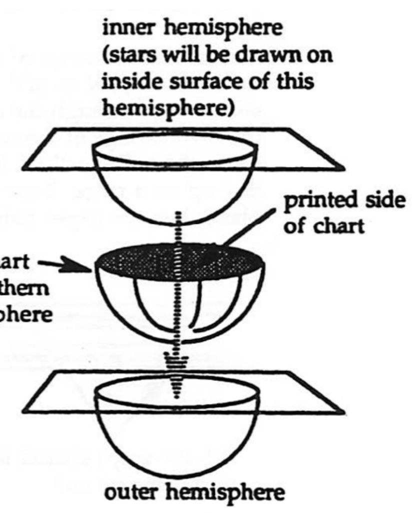
- 2 plastic hemispheres
- star chart sheets - north and south
- ecliptic strip sheet
- metal coat hanger
- small earth globe
- scissors
- tape
- pens (dry erase or transparency)
- Hawaiian Star Compass
- wood base
- blocks (to adjust height of wood base)
- paper horizon collar
- paper clips
- protractor
- wire cutter
- yellow dot sticker
- ruler

Procedure A

1. If you are 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 **<u>southern</u>** sky on the **<u>outside</u>** of a plastic hemisphere with the **<u>printed side facing down</u>.** 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.

Fig. 1



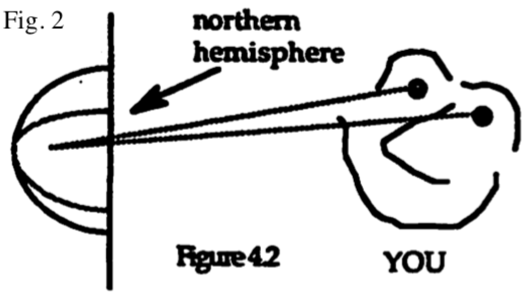
3. **Mark the stars** on the inside of the hemisphere with the pen. **Draw the lines** that mark the ecliptic and some of the brighter constellations. You may wish to use different color pens for the ecliptic and the constellation lines. The brighter stars are indicated by bigger symbols. (The "magnitude" of a star is an indication of its brightness. On this chart the brightest stars are zero magnitude and the dimmest stars fourth 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.

What Do You Think?

Look into the opening (the concave side of the hemisphere) of the northern hemisphere. (See Figure 2.) Discuss with your team members and write individual answers to questions on a separate sheet of paper.

Fig. 2



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?

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.

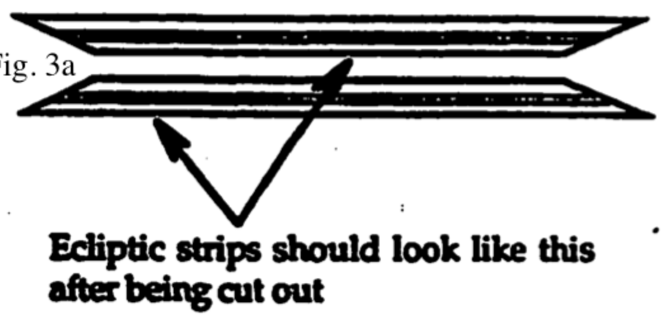
The constellations with lines on the **southern hemisphere** are:

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

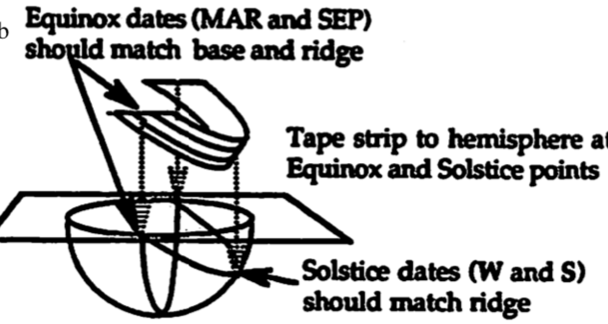
Procedure A - continued

5. **<u>Cut</u>** out the two transparent strips of dates on the ecliptic chart. (See Figure 3a.) **<u>Tape</u>** the MAR to JUN to SEP strip onto the **<u>outside</u>** of the northern hemisphere (See Figure 3b). T*he ecliptic line on the hemisphere should pass through the center line dates on the strip. The S mark in JUN should line up with the middle ridge of the northern hemisphere.* **<u>Tape</u>** 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 line up on a ridge.*

Fig. 3a



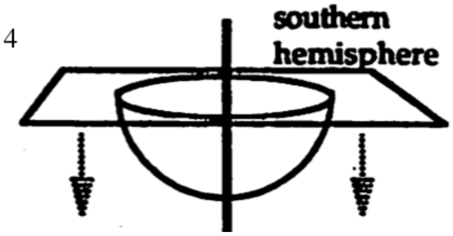
3b



6. **<u>Cut</u>** a wire coat hanger with wire cutters so that you have a straight rod with a hook on one end. Watch out! The end of the wire could puncture your eye or skin! Wrap the end of the hook with tape to prevent injury (or use the rubber cap from the hanger).

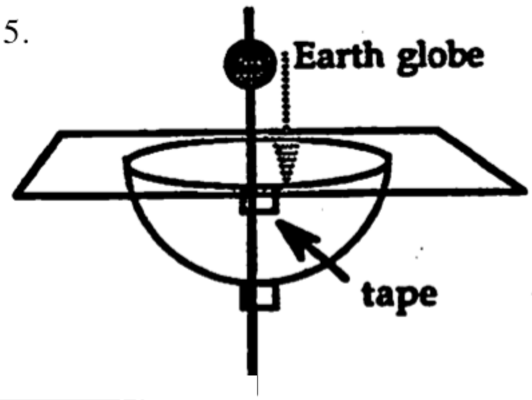
7. **<u>Push</u>** the coat hanger wire through the hole in the northern hemisphere from the outside to the inside. (If you don't have holes already, make them with a push pin.) Wrap a piece of tape around the wire leaving about five inches outside the spheres. This tape will hold the northern hemisphere in place.

Fig. 4



8. 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. Refer to Figure 5.

Fig 5.



9. **Push** the wire through the celestial pole of the southern hemisphere so the opening of the two hemisphere face each other.

10. **Rotate** the hemisphere until the points where the ecliptic touches the equator **match** on both hemispheres. (*The ecliptic should completely encircle the sphere and should pass both above and below the equator as shown in Figure 6.*)

11. **Tape** the edges of your two spheres together on the four corners.

12. **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. Refer to Figure 7.

Fig. 6

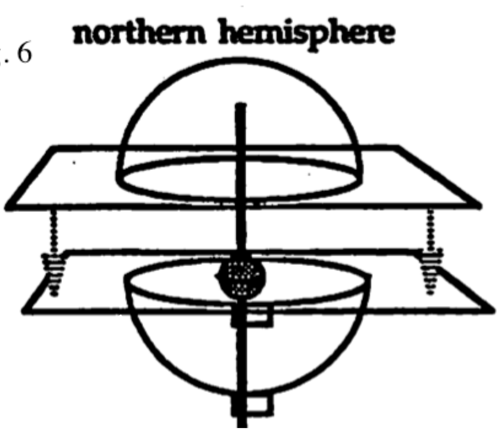
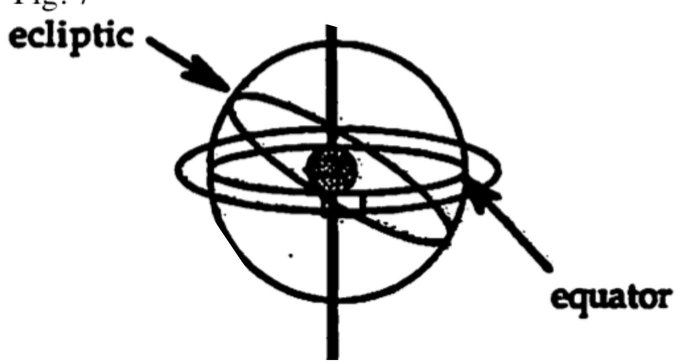


Fig. 7

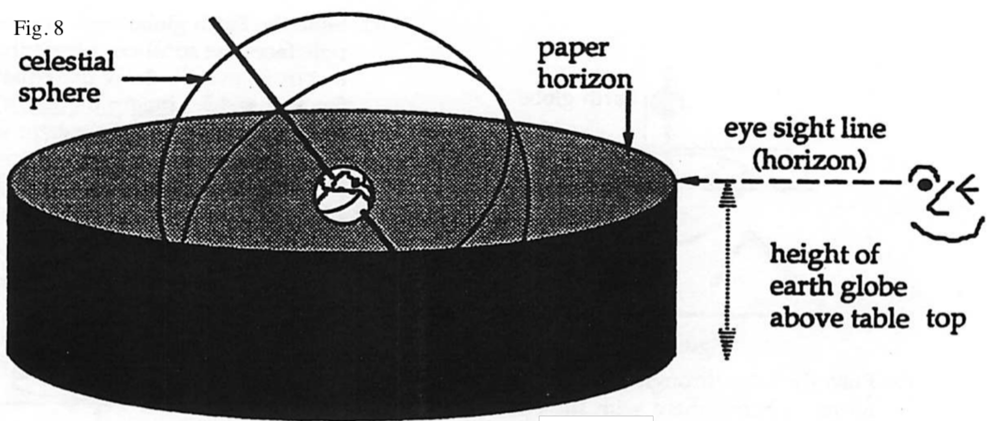


13. **Gently push** the wire through the wooden block. Measure the angle between the wire and the horizontal. It should be approximately the latitude of Hilo (19°43'), approximately 20°.

14. **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 one sees where the sky touches the earth. The celestial sphere should be able to sit inside the paper loop. Tighten the horizon around the sphere using paper clips.

15. Use blocks or other objects you can find 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 table top and make sure that it's the same as the height of the paper horizon loop.

Fig. 8



Familiarize yourself with 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 (N.C.P. and S.C.P.) and imaginary lines such as the Celestial Equator 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 observers zenith in every direction. If the observer where 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 hanger wire 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 hemisphere 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.

Fig. 9

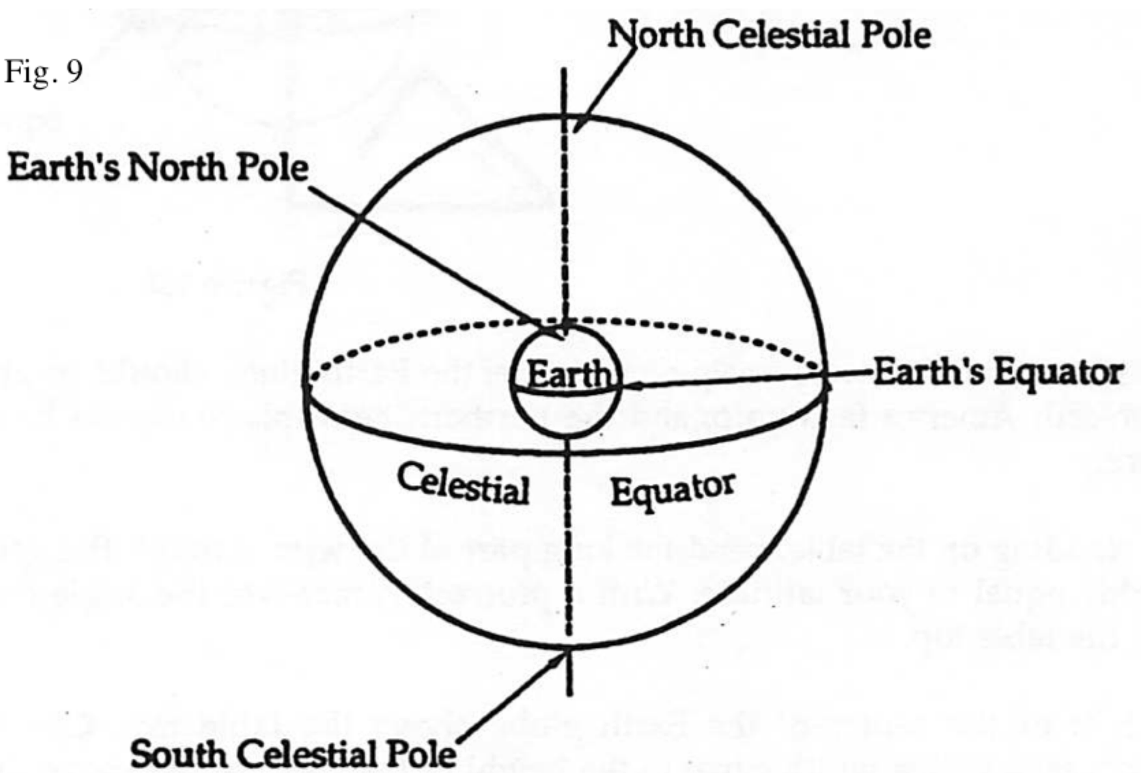


Fig. 10

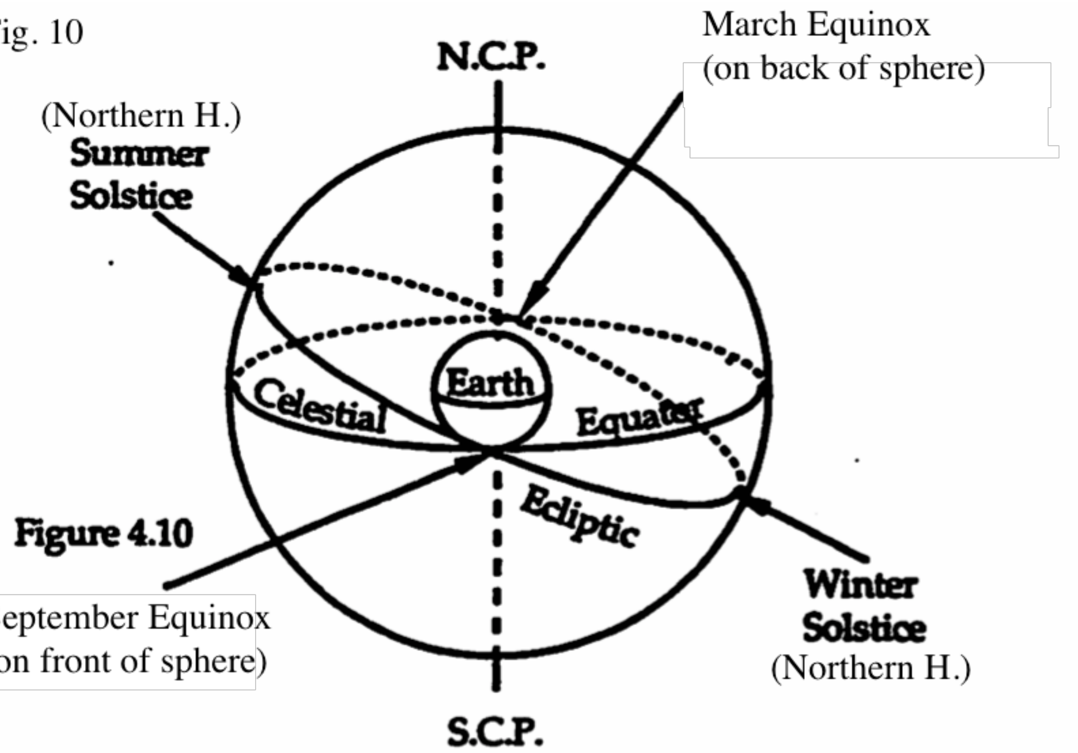
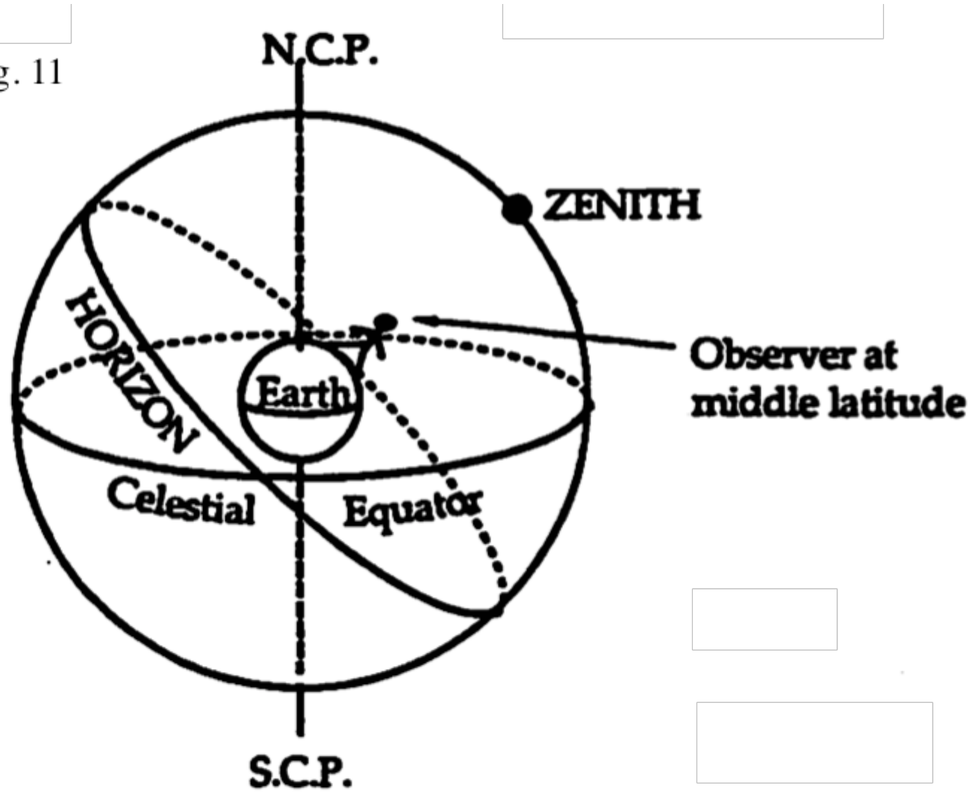

N.C.P.
March Equinox
(on back of sphere)
(Northern H.)
Summer
Solstice
Earth
Celestial
Equator
Ecliptic
Figure 4.10
September Equinox
(on front of sphere)
Winter
Solstice
(Northern H.)
S.C.P.

Fig. 11


N.C.P.
ZENITH
Observer at
middle latitude
HORIZON
Earth
Celestial
Equator
S.C.P.

Modeling the Sun's Daily Motion

Procedure B

1. On the ecliptic, **locate** the date that you made the observation from last week. **Mark** this date with a yellow dot sticker.

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 (NSEW) 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 globe. **Turn** the sphere on its axis until the Sun marker 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, 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 yellow dot. When the yellow dot is leveled with the top of the collar, it's at the sunset position.

Discussion Questions

Write individual answers to questions on a separate sheet of paper. Discuss the questions with your team members.

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. There are 24 bumps on the flat surfaces at the sphere's equator, each bump to bump interval represents one hour of time.

Q3: **Turn** the sphere to move the Sun marker from sunrise to sunset. **Count** intervals that pass the western horizon. This is the number of hours of daylight in one day.

a) About **how many hours** of day light were there in that day?

b) What **fraction of a 24-hour day** is represented by the turn you gave the sphere?

c) Ask the instructor or teaching assistant to obtain the actual daylight period for the date you did last week's activity. How did the actual time compare with the celestial sphere time?

Q4: **Compare** the path of the Sun as demonstrated with your celestial sphere to the path you plotted on the hemisphere last week. How are they the same and how are they different? Write about 100 words.

Q5: **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.
b) Name a constellation near zenith.
c) Describe the position of the Big Dipper in the sky.
d) Name a constellation that is just rising. Specify the direction where it is rising.
e) Name a constellation that is below the horizon and cannot be seen at this time.