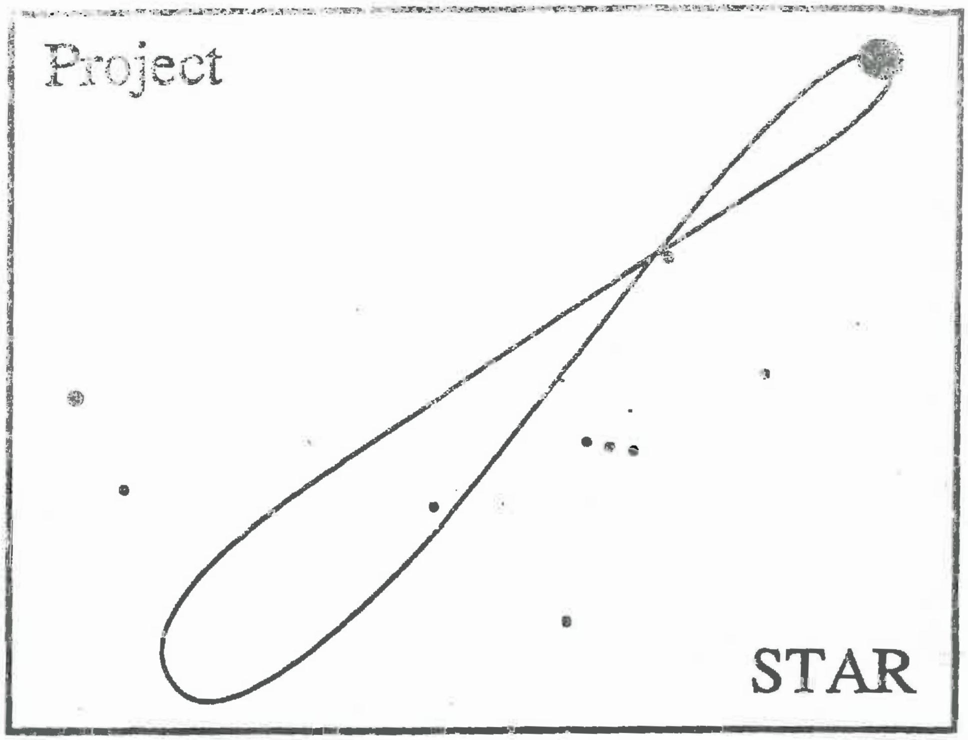
# 654-0030 654-0035 (PS-02) Project STAR Celestial Sphere Kit




Science Teaching through its Astronomical Roots

## Celestial Sphere Kit
## Teacher's Notes and Activities

Abstracted from the Project STAR activity book, Where We Are in Space and Time.

# Project STAR Activities

Project STAR (Science Teaching through its Astronomical Roots) began with a grant from the National Science Foundation (NSF) in December 1985. Since July 1986, high school astronomy teachers and scientists at the Harvard Smithsonian Center for Astrophysics have been developing and testing a variety of hands-on activities. These activities are designed to teach basic astronomical and mathematical concepts. STAR activities are unique in that they take into consideration the preconceptions (or misconceptions) that students may possess on entering your course. Students are asked to commit to their preconceptions by filling in the What Do You Think? section at the beginning of each activity. We must stress that the STAR curriculum emphasizes concepts over content; please consider this in planning the use of the STAR activities you have purchased. The activities in this kit, as with most science labs, require some teacher guidance. We strongly recommend doing the activities yourself before using them in class. However, you should allow your students to work with the materials as freely as possible. The key to the success of preconception-based learning is the student's discovery of his or her preconceptions and their abandonment in favor of more powerful concepts through the personal experience offered by the activities.

The activities in this kit are taken from the 1989-90 STAR Activity Manual "Where We Are in Space and Time." The original activity numbering sequence has been retained for the benefit of those teachers who purchase more than one kit or have bought the complete manual. The activities should be done in numerical order to obtain the most effective results. You may have found some "extra" activities in your kit; these were included because we felt that they would provide important experiences in support of the principal activity you ordered. Please read the Teacher's Notes for the kit for specialized instructions, answers to questions, tips, and other information. You have permission to make as many photocopies of the activities in the kit as you need for your classes. Permission for any other use of the materials in this kit must be requested in writing on your school stationery and mailed to:

STAR Activities
Center for Astrophysics
60 Garden Street, MS-71
Cambridge, MA 02138

Questions concerning activities can be sent to the address above. Inquiries about orders must be sent to:

**Science First®**
**86475 Gene Lasserre Blvd.**
**Yulee, FL 32097**
**1-800-875-3214**

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# TEACHER'S NOTES
# PROJECT STAR
# CELESTIAL SPHERE KIT

## Activity 1: Keeping A Journal Of The Sun's Motion

### 1. Preconceptions

There is one What Do You Think? question in Activity 1, Question 1.1. This asks the student to consider what she or he thinks about the time and position of sunset over a three-month period. While most students will be aware that the Sun sets earlier between September and December, they may not be aware that the position of sunset shifts along the horizon (many believe the Sun always sets due west), or in which direction it shifts, or at what rate changes in sunset time and position occur. In this case, the Sun will set progressively southward, with a greater shift in position and time between September 21 and October 21 than between November 21 and December 21. At this point they are only being asked to commit to their ideas; the true pattern and its causes will emerge as a result of doing Activities 1 and 6.

### 2. Activity Tips

This activity requires the student to draw a western horizon and then plot the position of the setting Sun on a weekly basis for several weeks (six weeks minimum is suggested, with observations once a week). Many students have difficulty drawing an accurate horizon. Quite apart from any artistic problems, students simply have had little or no practice in drawing such a view. It may be helpful to have your students practice drawing views out the classroom window, or even views within the classroom. You can then examine the drawings for inaccuracies. Whether or not you have practice sessions, have your students bring in their sunset plots after the first couple of observations for you to check.

It is very important that each student locates a precise spot from which to make observations. The instructions direct the student to mark this spot in some way. Because objects at various distances from the observer will be used to locate the Sun's setting points, even slight displacements from the original observing spot can create errors due to parallax. The amount of parallax error is related to the distance to the landmark object: the closer the object is to the observer, the more likely it is that a small shift in the observer's position will cause an error. Caution your students to mark their observing spot and to make their observations from this same exact spot each time.

Your students may ask you when the Sun is considered to be setting, e.g., when it first touches the horizon or when it is completely below the horizon. Since the Sun is about one-half degree in apparent diameter, a sunset (or sunrise) has a duration of at least two minutes, rather than being a precise time. You should specify a "standard sunset" for your class, e.g., when the Sun has fully disappeared below the horizon.

There are students who will find this activity tedious and will not give it their full attention. Pressed with a deadline and a minimum number of observations for credit, these students may fill in some "missing" sunsets by interpolating from their own observations or those of other students. If you keep a daily record of the weather at sunset for the entire activity period, you can discount some "sightings" on the basis that the sky was overcast or it was raining on those dates. Carefully note the dates and times of student observations; unless two students are literally standing side-by-side making their sightings, no two students should have the same set of dates and times. Even a slight difference in location can cause the Sun to set considerably earlier or later.

Separate from the problem of the "inventive" student's results are variations that may occur over which the student has little, if any, control. The student is instructed to note the observing location on the sheet; if you know the area well enough, this will help you take some of these variations into account. Unless all your students are viewing from sites with unobstructed horizons, objects rising above the true horizon or differences in elevation will affect when a student sees the Sun set. For example, a student living in a valley may see the Sun set behind a hill at 4:00 p.m., while a student living atop that hill will not see sunset for perhaps another hour or more. (Have your students consider why clouds still glow after sunset, or why satellites are visible two or three hours after sunset, but not in the middle of the night. These objects are visible only because they are reflecting sunlight, so they must be in sunlight, meaning that the Sun has not set as seen from their position.) A student with an uneven horizon may record an irregular pattern of times. These sightings are controllable only to the extent that the student is willing and able to travel to a "best site." Consider these natural variations in times when going over student charts. There are, however, basic patterns to look for. Observations done between the Summer Solstice (June 22) and the Winter Solstice (December 21) should show the Sun setting progressively farther to the south, with the most rapid changes in sunset time and position occurring around the Autumnal Equinox (September 21). Similarly, observations between the Winter Solstice and the Summer Solstice should display a shift in sunset position northward, with the most rapid changes taking place around the Vernal Equinox (March 20). Sunset times printed in the local paper or an almanac can be used as a guide, but should not be used as exact times. (These printed times are sometimes used by the inventive student.)

Some students may complain of difficulties making sightings because they work in the evening. If it is truly impossible for sunset observations to be made in the evening, suggest that they do *sunrise* observations. The chart then becomes one of the *eastern* horizon. (You may be surprised how many students can resolve their work schedules when faced with the prospect of a 6:00 a.m. observation.) Weather is another difficulty. For the sake of convenience, many students will want to set aside the same evening each week for their observation. In some areas the weather is predictable enough to allow this. It is more likely, however, that every Thursday evening cannot be guaranteed to be clear. Encourage your students to keep track of weather forecasts and be ready to make an "early" observation if the next several days may be overcast. (This activity has been done successfully using this technique in such notoriously unstable climates as New England and the Great Lakes region.)

### 3. Answers to Questions

The answers to Questions 1.2-1.8 will vary depending on the time of year the activity is done. Refer to the Activity Tips for general patterns of time and position.

## Activity 3: Plotting The Daily Motion Of The Sun

### 1. Preconceptions

Questions 3.1-3.5 constitute the What Do You Think? section of Activity 3. These questions ask what the student believes about the path of the Sun across the sky on a given day, including directions of sunrise and sunset and the number of hours of daylight. Most students think that the Sun rises due east, passes directly overhead at noon, and sets due west. The path plotted for 3.1 is therefore often a simple arc from east, through the zenith, and down to the west. The idea that the Sun is overhead at noon, regardless of the time of year, is very strongly held among students of all ages and academic backgrounds. Expect a number of students to state 12 hours for 3.5; others may be more aware that the days have been getting longer or shorter and respond with values more or less than 12 hours. This activity will directly test these ideas for the date the activity is done. In combination with Activities 1 and 6, additional insight into patterns and their causes will be gained.

### 2. Activity Tips

The plastic hemispheres are quite durable; they may dimple if too much pressure is applied with the marking pen, but the dome will easily pop back into shape.

Depending on the size of your class, schedule, and access to an area where the hemispheres can be set out on the ground, you may wish to vary Step 3. As written, the plotting portion of the activity is designed to be completed in one period. However, if you can leave the hemispheres in place for a day, you can have different classes plot positions over the day, or arrange to have students come back during study periods or lunch to continue the plotting. This would be similar to doing Extension 2 in school.

If you are going to be plotting paths for selected days over a period of time (such as Extension 3), you may want to use a grease pencil instead of a felt-tip marker; many felt-tip inks fade on this plastic over a period of days or weeks. If you have time, you might want to experiment with your felt-tips to see how fade-resistant they are.

Note that the alignment of the hemispheres by magnetic compass should take into account the magnetic declination at your location. A declination map for the continental United States is appended to these notes for your reference or to be photocopied for student use.

### 3. Answers to Questions

The answers to Questions 3.6-3.9 will vary with the time of year and your location. See the Activity Tips for Activity 1 for general patterns. For Question 3.8, the answer should be close to due south, and not directly overhead. By definition, the Sun is directly south at local apparent noon. However, local noon usually does not coincide with 12 noon by the clock due to factors such as daylight savings time and your position east or west of the central meridian of your time zone. (The time zone meridians, or longitudes, for the continental U.S. are: Eastern = 75 degrees West, Central = 90 degrees West, Mountain = 105 degrees West, and Pacific = 120 degrees West. Find your longitude on a map or in an atlas. If you are east of your zone's meridian, the Sun will be at its noon position before 12:00 standard time; if you are west of the meridian, local noon will occur after 12:00 standard time.) At local noon the Sun is also at its highest point in the sky for the day, but it is *never* directly overhead at noon (or at any other time) for any location in the continental U.S. Only locations on or between the Tropics of Cancer and Capricorn, 23.5 degrees North and South latitude respectively, ever see the Sun exactly overhead, and then only on two days out of the entire year (one day on the Tropic lines).

## Activity 4: Building And Using A Celestial Sphere

### 1. Preconceptions

As this is an assembly activity, there are no What Do You Think? questions. You should stress to your students that the celestial sphere is only a model: the Earth is not really in the center of the stars, the stars are not equidistant from the Earth, and the Sun does not go around the Earth. However, since many celestial motions behave *as if* they were centered on the Earth, the celestial sphere is a useful model for investigating these motions. This would be a good place to comment on scientific theories in general, for they are all models of one sort or another (some are very abstract mathematical equations) that attempt to match our observations, but do not necessarily duplicate nature exactly. The celestial sphere is a very ancient physical model and its original theory (the Earth is at the center of the universe) has been disproved. But the sphere is still an excellent tool.

## 2. Activity Tips

### Activity 4A:

A very neat sphere will result if the student takes the time to carefully follow the directions in Activity 4A. The assembly often takes three or more periods. You can either let the students work at their own rate or take the class through the steps as a group. It is preferable to let the students pace themselves; those who work quickly and accurately can help their peers with difficulties. However, if your class is large and time is limited, you can "walk" them through the procedure step by step.

Be aware of the steps in the assembly where the student is asked to show you her or his work before proceeding. It is recommended that you assemble your own sphere ahead of time to note problem areas. Your completed sphere can then serve as a model for the students. (Save your cut-out star charts and have an extra coat hanger bent as a stand to serve as additional references.)

Depending on your students' abilities, you may want to do certain tasks yourself. Cutting the coat hanger is one example as this has the potential for causing injury if done carelessly. If you have assembled a sphere yourself, you can note those steps that you might prefer to do or have done by the student under your direct supervision.

Step 2 is crucial. If the ecliptic line on the star chart does not end at a ridge on the hemisphere, the hemispheres will not fit together with the ridges matching. The assembled sphere will look awkward and be confusing to use.

Step 8: The paper zodiac strip supplements the ecliptic marked on the star chart. It is important that this strip be securely fastened to the inside of the hemispheres, especially if the students will be using map pins for the Sun.

Step 9: The heavier the wire in the coat hanger, the better. Thin wire hangers make flimsy supports that bend under the weight of the sphere. The simplest way to bend the coat hanger is to leave one original curve as part of the base and straighten the other curve to form the axis for the sphere. Only one additional bend then has to be made below the sphere to form a stable base, roughly triangular in shape. Some small adjustments may be needed for maximum stability. Be sure that the sphere is mounted fairly low on the axis; the higher it is mounted, the more top-heavy the assembly will be and the harder it will be to balance it on the base. Step 10 recommends mounting the southern hemisphere about one inch above the last bend in the wire.

Steps 18 & 19: The horizon collar is what allows the sphere to demonstrate sunrise/sunset positions and length of day. Its height must be measured accurately once the sphere's axis has been bent to your latitude angle. THE WIDTH OF THE COLLAR EQUALS THE HEIGHT OF THE <u>CENTER</u> OF THE EARTH GLOBE ABOVE THE TABLE TOP. THE GLOBE <u>MUST</u> BE VIEWED AT <u>EYE LEVEL</u> TO ACCURATELY MEASURE ITS HEIGHT. See Figure 4.8. Note that the collar is useful only for your latitude. If you want your students to experiment with conditions at other northern latitudes (the sphere would have to be mounted upside-down on the axis to model the southern hemisphere), the wire must be bent to the new latitude angle and the horizon collar's height increased or decreased accordingly.

### Activity 4B:

Activity 4B lets the student use the sphere for the first time. The plotting data from Activity 3, if done, provide a useful set of conditions to model. Turning the sphere represents the rotation of the Earth on its axis, while moving the Sun marker represents the revolution of the Earth around the Sun. The amount of rotation in hours can be determined by counting the number of bumps on the edge of the sphere that either rise above the eastern edge of the horizon collar, or the number of bumps that set below the western edge of the collar: one bump represents one hour.

### 3. Answers to Questions

4.1 Polaris (or the North Star).

4.2 The Big Dipper (a portion of Ursa Major, the Big Bear), specifically the two stars on the outer edge of the "bowl," commonly called the "pointer stars."

The answers to Questions 4.3-4.5 will depend upon the date Activity 3 was done and your location. See Activity Tips for Activity 1 for general patterns.

## Activity 6: Modeling The Reasons For The Seasons

### 1. Preconceptions

The What Do You Think? section includes Questions 6.1-6.4. These probe student ideas concerning the causes of the seasons. Confronted with the two photographs of the Sun taken six months apart, most students (and adults) select the larger image as having been taken in June (or some other summer month) and the smaller image having been taken in December (or another winter month). It is a deeply held and widespread misconception that the Earth is closer to the Sun in summer than it is in winter. It certainly seems to make sense. However, the Earth is actually closest to the Sun around January 4 (perihelion) and farthest from the Sun on about July 5 (aphelion). While it is true that the Sun's heating effect increases as the distance from the Sun decreases, the change in heating due to the relatively slight difference in distance between perihelion and aphelion (about 3 million miles, compared to an average distance of 93 million miles) is overshadowed by the effect caused by the much greater change in the angle of the Sun's rays and the number of hours of daylight. Thus the most significant factor in causing the seasons is the tilt of the Earth's axis, not the shape of its orbit. Activities 6A and 6B are designed to provide evidence downplaying the role of orbital eccentricity and emphasizing the effects of the tilt of the Earth's axis. Activity 6A demonstrates that the Earth's orbit is very nearly circular and that perihelion occurs during the northern hemisphere winter. Activity 6B takes the student through the seasons to obtain data on length of day and the height of the Sun at your latitude. The observations from Activity 1 can also be modeled as part of 6B; in this way, students can see why their sunset observations showed the changes they did.

### 2. Activity Tips

**Activity 6A:**

Activity 6A has students plot the orbit of the Earth from images of the Sun taken once a month for one year. Two plotting graphs (Graph 6.1) are provided, one in metric units, the other in English units.

Step 2: The images on Chart 6.1 are aligned along their left-hand edges. You may want to have your students use a ruler to draw a baseline along the left-hand edges to facilitate measuring the image lengths; use the first two images to establish this line as they have the sharpest left-hand edges. The right-hand edges are fuzzy, but an edge can be discerned for each image with careful examination. If you look at the right-hand edges of the images from a distance, or view the images at an angle by tilting the page away from you, you can see that the image lengths are not same and do follow a pattern of decreasing-increasing lengths. Reasonable values for image lengths are:

January 12: 11.8 cm
February 11: 11.7 cm
March 26: 11.6 cm
April 10: 11.5 cm
May 23: 11.4 cm
June 15: 11.3 cm

July 12: 11.3 cm
August 17: 11.4 cm
September 14: 11.5 cm
October 15: 11.6 cm
November 15: 11.7 cm
December 15: 11.8 cm

Step 3: The metric factor was obtained by multiplying the average Earth-Sun distance, 150,000,000 km, by the average length of the 12 images on Chart 6.1, 11.3 cm, and then rounding off. The English factor was derived by multiplying the average Earth-Sun distance, 93,000,000 miles, by 11.3 cm, and then rounding off. Either factor yields approximate distance values. Although approximation and rounding off are used here, the resulting drawing of the Earth's orbit (graph 6.1) is very accurate at the scale it is drawn.

3. Answers to Questions

6.5 The curve represents the orbit of the Earth around the Sun. The curve is very nearly a perfect circle.

6.6 Based on the image lengths, the Earth is farthest from the Sun in June or July. Interpolation of the results for June 15 and July 12, or examination of Graph 6.1, suggests that aphelion occurs near July 1, which is true.

6.7 Based on the image lengths, the Earth is closest to the Sun in December or January. Interpolation of the results for December 15 and January 12, or examination of Graph 6.1, suggests that perihelion occurs near January 1, which is true.

6.8 Results of this comparison vary with student predictions, but most students will have predictions opposite from their results.

6.9 Graph 6.1 shows the path of the Earth around the Sun. It shows that this path is very nearly a circle. It also shows that the Earth is closest to the Sun in January and farthest from the Sun in July.

6.10 The difference in the apparent size of the Sun can only be explained by one of two choices. Either the Sun actually expands and contracts in size during this period, or the distance between the Earth and the Sun changes, with the Sun appearing larger when the Earth is nearer to it. (Data not presented in this activity confirm that it is the distance between the Sun and the Earth that changes, not the actual diameter of the Sun. For example, if the Sun really did expand and contract as much as the photos show, it would mean that the Sun is a very unstable star and its brightness would be changing significantly, something we do not observe.)

6.11 It is warmest in July or August (for locations in the continental U.S. under average weather conditions). The Earth is closest to the Sun in January, when the weather is normally at its coldest. The distance between the Earth and the Sun therefore cannot be the main cause of the seasons. Some other factor(s) must be at work.

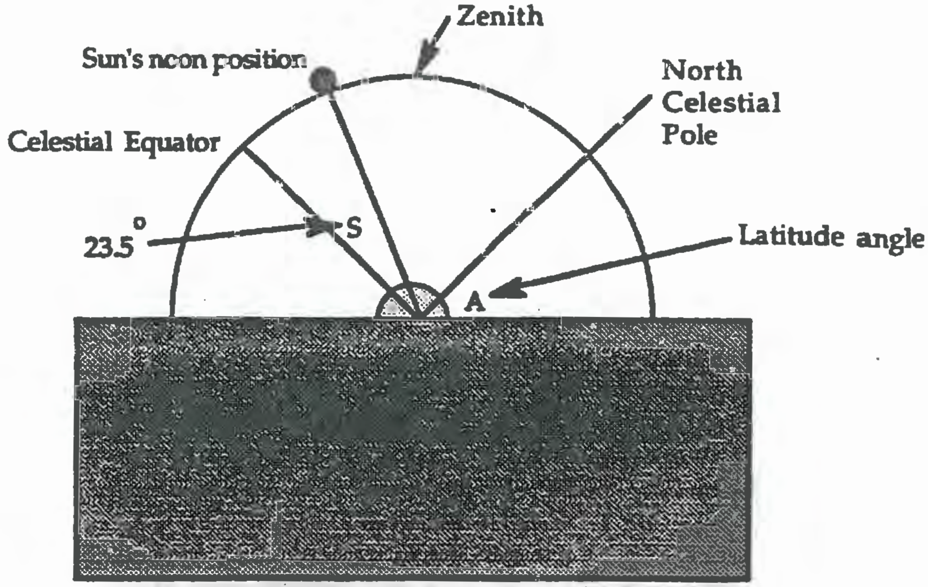
All answers for the following questions are for locations in the continental United States.

6.12 Northeast.

6.13 Northwest.

6.14 Between 14 and 15 hours.

6.15




6.16 Ursa Major, the Big Bear (the Big Dipper).

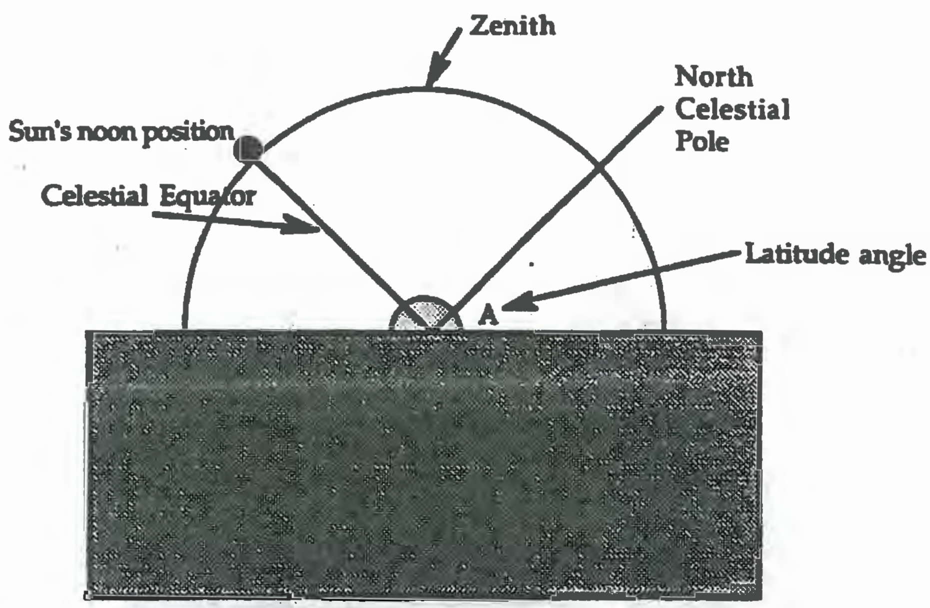
6.17 Cygnus, the Swan (the Northern Cross).

6.18 East.

6.19 West.

6.20 12 hours.

6.21




6.22 Scorpius (the Scorpion) and Sagittarius (the Archer).

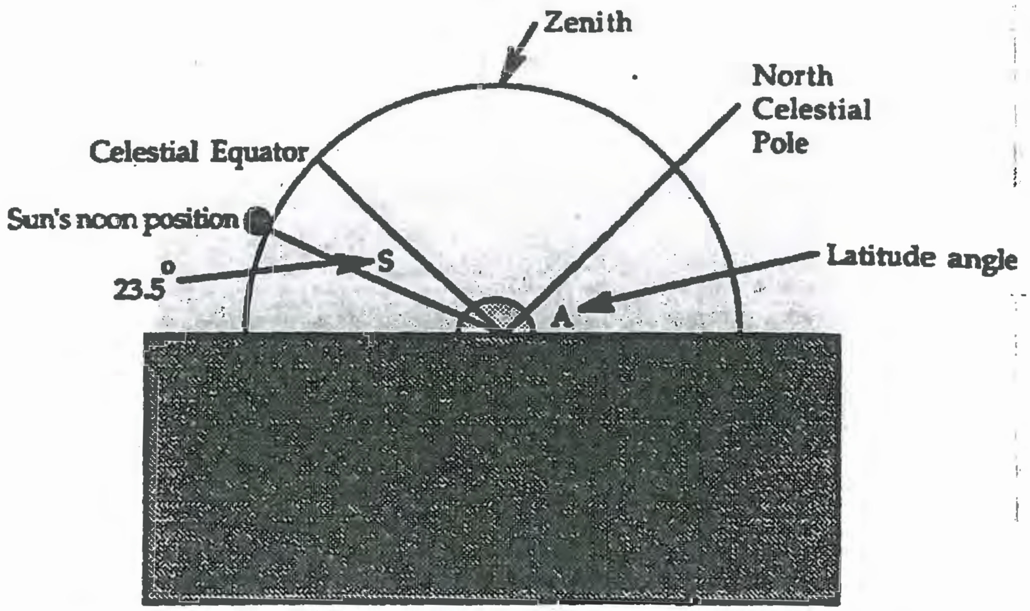
6.23 Cygnus is near the zenith.

6.24 Southeast.

6.25 Southwest.

6.26 Between 9 and 10 hours.

6.27




6.28 Taurus (the Bull), Gemini (the Twins), Orion (the Hunter).

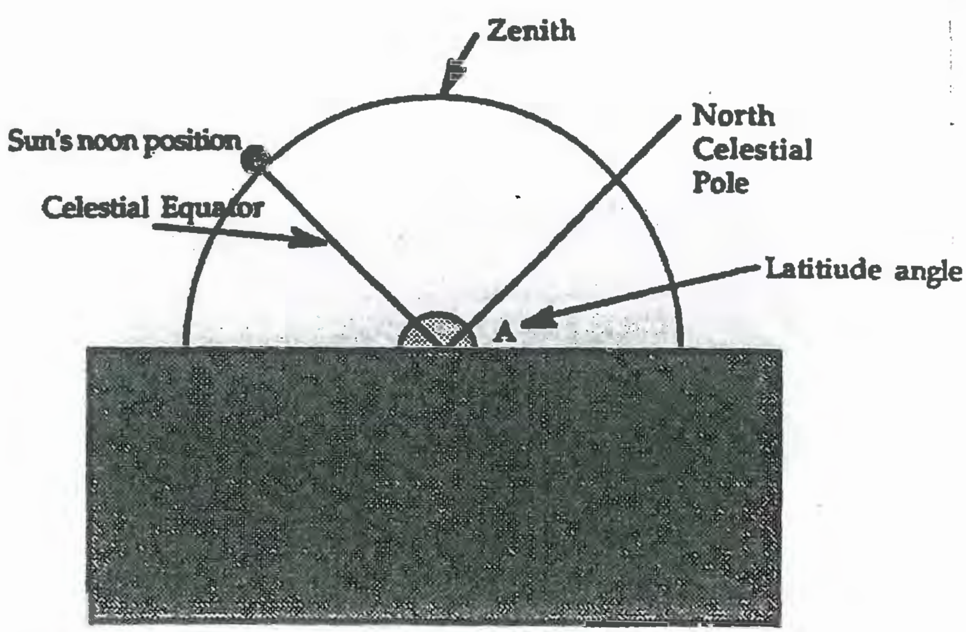
6.29 Cygnus, the Swan.

6.30 East.

6.31 West.

6.32 12 hours.

6.33



6.34 About halfway between the southern horizon and the zenith.

6.35 Leo, the Lion.

6.36 a) No.

b) Summer: Northeast; Autumn: East; Winter: Southeast; Spring: East.

6.37 a) No.

b) Summer: Northwest; Autumn: West; Winter: Southwest; Spring: West.

6.38 a) The answer depends upon the accuracy of the Activity 1 observations.

b) The position of sunset shifted from due west to southwest.

c) The answer depends upon the time of year, but should be consistent with the findings of Activity 6B.

6.39 a) The number of hours of daylight decreased by about 2 or 3 hours.

b) The number of hours of daylight decreased by about 2 or 3 hours.

c) The number of hours of daylight increased by about 2 or 3 hours.

d) The number of hours of daylight increased by about 2 or 3 hours.

6.40 The difference in daylight hours between the longest day and the shortest day is between 4 and 6 hours.

6.41 a) The Sun was lower in the sky.

b) The Sun was lower in the sky.

c) The Sun was higher in the sky.

d) The Sun was higher in the sky.

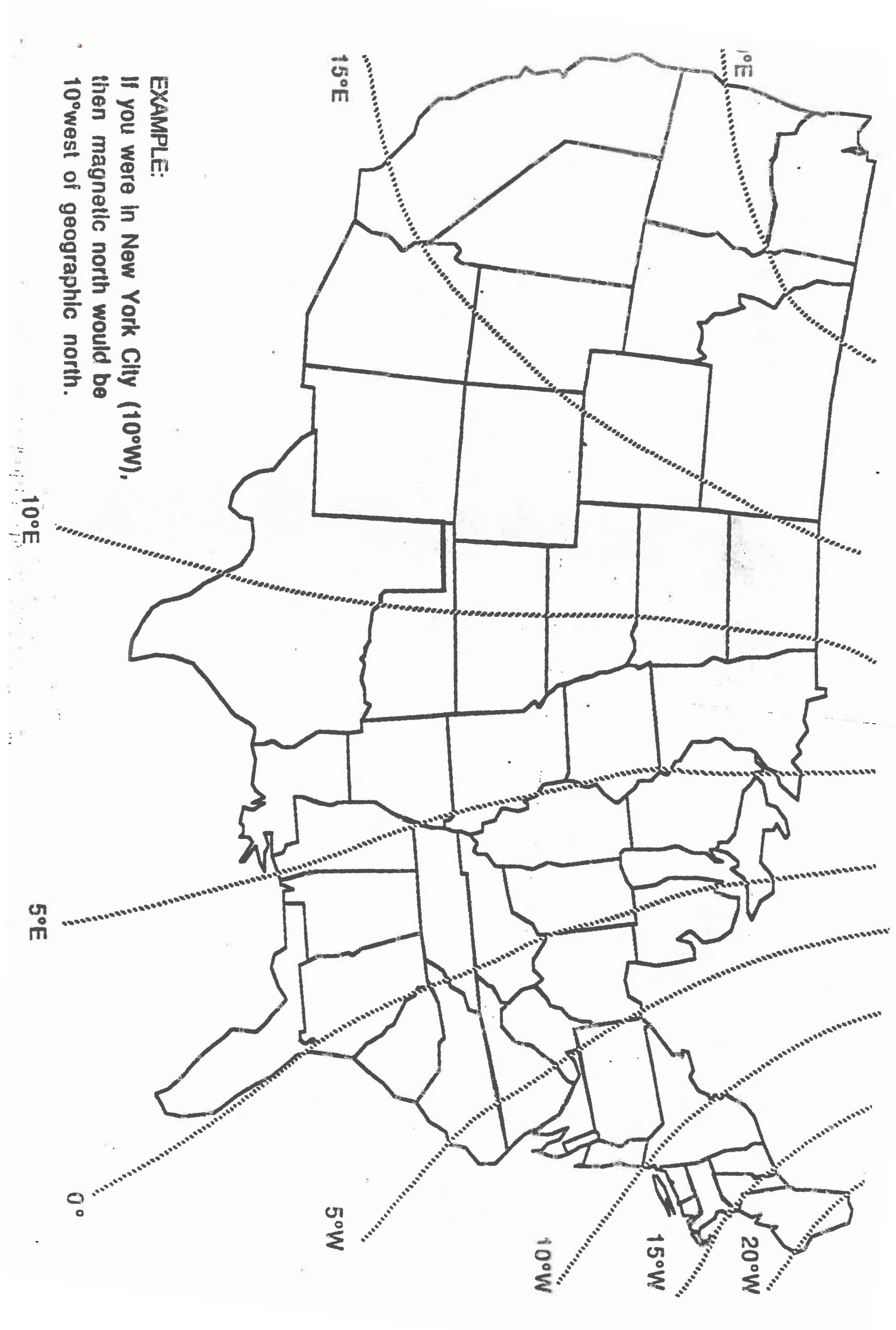
6.42 No. On no date of the year is the Sun directly overhead at noon, or at any other time, for any location in the continental United States.

6.43 a) When the Earth is closer to the Sun, the Earth is warmer. When the Sun is higher in the sky, the Sun's rays are more direct (closer to being perpendicular to the Earth's surface), which causes greater heating. Also, when the Sun is higher in the sky the daylight period is longer and the Sun has more time to heat the Earth.

b) The changes in the angle of the Sun above the horizon are linked to changes in season. The changes in the distance between the Earth and the Sun do not coincide with changes in the seasons (although the Sun's heating effect *is* greater when the Earth is closer to it). Therefore, the changes in the Sun angle must play a much greater role in causing the seasons than the changing Earth-Sun distance. The minor increase in heating caused by being slightly nearer to the Sun in January must be overwhelmed by the significant decrease in heating caused by the much lower Sun angle (and much shorter daylight period). It is the tilt of the Earth's axis, not the shape of the Earth's orbit, that controls the seasons on our planet.

6.44 Summer: Setting in the west. Autumn: Below the horizon. Winter: Rising in the east. Spring: About halfway across the sky.

# DIFFERENCE BETWEEN MAGNETIC AND GEOGRAPHIC NORTH.



## ACTIVITY 1 KEEPING A JOURNAL OF THE SUN'S MOTION

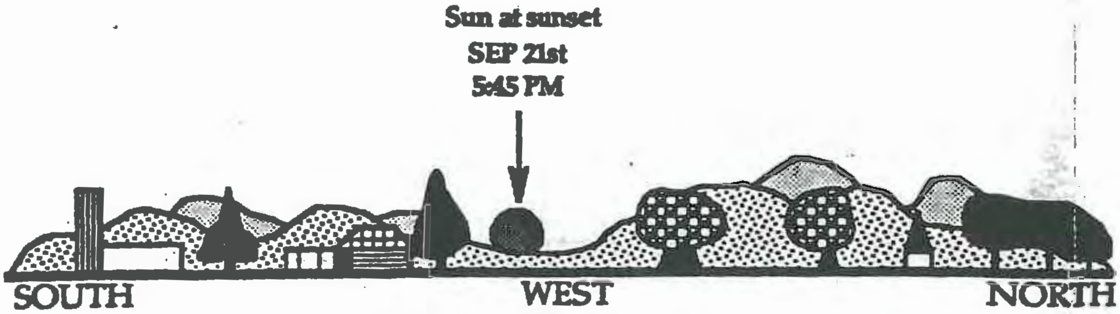
**PURPOSE**

To record observations of sunset from the same location, once a week, for a period of several weeks.

**WHAT DO YOU THINK?**

Write the answers to questions and problems in the spaces provided.

1.1 *The illustration below shows a site in the continental United States with the Sun setting behind some distant objects on the horizon. On this illustration, draw the Sun where you think it will be at sunset on each of the dates given below.*




*Write the appropriate date above each Sun you draw and write what you think will be the time of each of these sunsets in the spaces below. (If your area is on Daylight Saving Time during the observation, subtract 1 hour from the time so that times will be expressed in Standard Time.)*

| | | | |
|---|---|---|---|
| *DATES:* | *SEP. 21* | *SUNSET TIME* | *5:45 p.m.* |
| | *OCT. 21* | *SUNSET TIME* | ________ |
| | *NOV. 21* | *SUNSET TIME* | ________ |
| | *DEC. 21* | *SUNSET TIME* | ________ |

**MATERIALS**

sheet of plain paper, 22 cm x 28 cm (8.5 in x 11 in) or larger
pencil (or try colored pencils, felt-tip pens, or paint on poster board)
magnetic directional compass
watch (time keeping device)
Chart 1.1

**PROCEDURE**

FIRST DAY: Getting Oriented

1. Find a location convenient to your home or work with as clear a view as possible of the western sky. When facing West, you should be able to look South (to your left) and North (to your right) without any major obstacles blocking your view. (NOTE: If you cannot accurately determine directions, call the point where the Sun is setting on the first day of observing West.)

2. Pick an exact spot for viewing that you will be able to locate each time you make an observation. Push a stick or stone into the ground, or make a scratch on a paved surface to help you find the spot. Make all your observations from this location.

3. On your sheet of paper, draw the horizon features (see Question 1.1 for an example). Include buildings, trees, power lines, hills, and anything else you can see. These landmarks will help you locate where the Sun sets on your diagram. Mark where North, South, and West are found along your horizon. Place West in the center of your drawing. Write the location (neighborhood and/or street name) of your observing spot on this chart.

4. As the Sun begins to disappear behind one of the landmarks you have marked, draw the Sun on the chart exactly as it appears in the sky. Write the time to the nearest minute and the date above your drawing of the Sun. Use Standard Time.

5. On Chart 1.1, keep a log of the weather and anything unusual you observe about the Sun or sky.

6. Make your observations of the sunset at least once a week, weather permitting. Your teacher will give you the beginning and ending dates for this activity.

Answer the following questions after completing all your observations.

*1.2 How did the position of sunset change during the period of your observations?*

*1.3 How did the time of sunset change during the period of your observations?*

*1.4 Why do you think the sunset position and time changed as they did?*

## DISCUSSION QUESTIONS

*1.5 If the Sun does not set at the same time each day, does it set earlier or later each day?*

*1.6 If the time of sunset is changing, how would the time of sunrise change (if at all)?*

*1.7 How did the number of hours of daylight change?*

*1.8 Compare your journal of the real sky to your predictions in Question 1.1.*

## QUESTIONS TO TEST YOURSELF

1. Does the Sun always set in the same compass direction?
2. How did the Sun's setting position change during your observation period?
3. Does the Sun always set at the same time?
4. How did the Sun's setting time change during your observation period?

## EXTENSIONS

1. Set up and keep a sunrise journal.
2. Continue this sunset journal through the rest of the school year.

## CHART 1.1 SUNSET JOURNAL

NAME: ______________________ CLASS: __________

LOCATION OF OBSERVATION SITE: ______________________________

| | DATE | TIME | SUNSET DIRECTION | SUN COLOR | WEATHER |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |

## ACTIVITY 3 PLOTTING THE DAILY MOTION OF THE SUN

### PURPOSE

To plot and discuss the Sun's apparent daily movement across the sky.

### WHAT DO YOU THINK?

Write the answers to questions and/or problems in the spaces supplied.

Place the square rim of the plastic hemisphere flat on your desk.

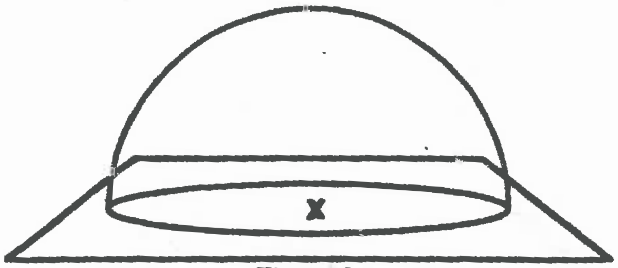


Figure 3.1

Imagine that the sky is the inside surface of the hemisphere. As an observer, you would be standing at the center of the circle at the base of the hemisphere. This is the spot marked X in Figure 3.1. You will draw the path of the Sun as it would appear from inside the hemisphere.

With the plastic hemisphere in front of you, choose a point on the base at one of the ridges to be North and label it "N." Looking down on the dome and going clockwise from North, use a transparency pen to mark the other three ridges as East (E), South (S), and West (W).

3.1 a) *Predict the following positions for the Sun for today by writing a letter on the dome. Use the letter r to show position of the Sun at sunrise; the letter n to indicate its position at noon; and the letter s to indicate its position at sunset.*

b) *Connect these points on the hemisphere with a curved line to show how you think the Sun will move across the sky today.*

3.2 *From what direction did the Sun rise this morning?* ____________________

3.3 *In what direction will the Sun set this evening?* ____________________

3.4 *Where in the sky is the Sun at noon?* ____________________

3.5 *How many hours of daylight will there be today?* ____________________

You will repeat this activity another day. Meanwhile, store your hemisphere in a safe place to prevent loss, damage, or smudging.

### MATERIALS

plastic hemisphere from the WHAT DO YOU THINK? section of this activity
marking pencil (use a grease pencil if possible; sunlight may fade felt-tip inks)
magnetic compass
Figure 3.3
transparent tape or stapler
cardboard sheet 20 cm x 20 cm (8 x 8 inches)

### PROCEDURE

1. Tape or staple Figure 3.3 (the "base sheet") to the piece of cardboard. Then tape or staple the base of the hemisphere to the base sheet-cardboard combination so that the ridge marked "N" lines up with North on the base sheet. See Figure 3.2.

2. Place the hemisphere on a flat, horizontal surface in direct sunlight. With the aid of a magnetic compass, turn the hemisphere so the ridge marked "N" points North. NOTE: Be careful not to place your hemisphere near iron or steel objects since these metals will attract your compass needle and produce an inaccurate reading. Once the dome is set in place DO NOT MOVE IT! (Draw an outline around the cardboard with a piece of chalk just in case the hemisphere is accidentally moved.)

DO NOT STARE AT THE SUN. IT CAN DAMAGE YOUR EYES.

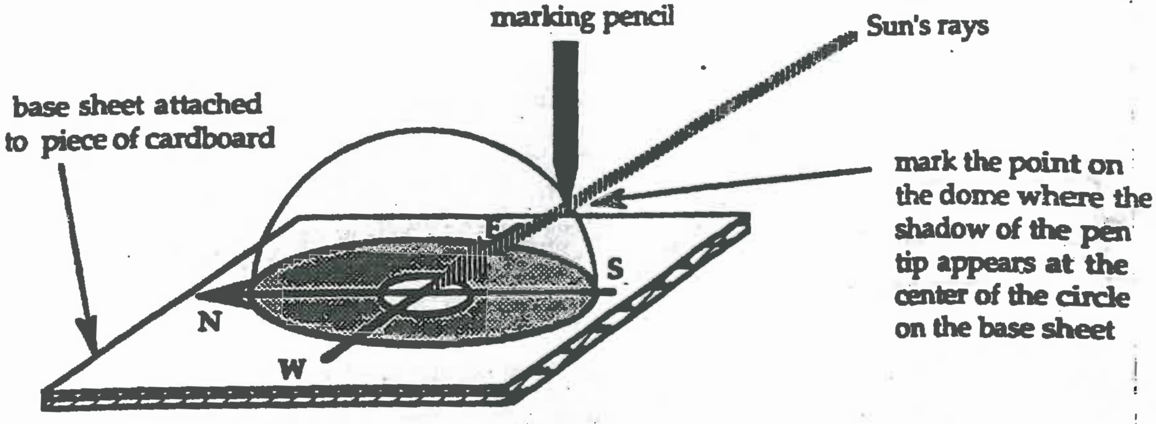



Figure 3.2

3. Plot the Sun's position in the following way (see Figure 3.2):

a) Carefully move the tip of the grease pencil close to the plastic hemisphere, but do not let the pencil touch the sphere.

b) Move the pencil around until the shadow cast by its tip falls directly on the + mark on the base sheet.

c) Touch the pencil tip to the dome and make a dot. The dot's shadow should fall directly on the + mark on the base sheet.

d) Repeat Steps (a) - (c) every 10 minutes for at least 30 minutes and longer if possible.

e) Connect the plotted points with a line. Draw this line on the inside of the hemisphere. Label the line with the date and time range. DO NOT ERASE THIS LINE.

## DISCUSSION QUESTIONS

3.6 *Discuss how the points and line you drew for Question 3.1 compare with the points and line plotted in this activity.*

3.7 *From what direction did the Sun rise?* _______________

3.8 *Where in the sky was the Sun seen at noon?* _______________

3.9 *In what direction did the Sun set?* _______________

When you have answered these questions, erase the line you drew for Question 3.1. Keep the line you plotted in step 3.

EXTENSION

1. Bring the hemisphere and a magnetic compass home on the same day you did this activity. Follow the set-up and plotting procedures described in Steps 2 and 3. Plot the Sun's motion across the sky for half an hour before sunset and for half an hour after sunrise the next morning. (You will have to wait a day if the sky is overcast at sunset or sunrise.) Label the lines with the dates and time ranges.

2. On a clear weekend day follow Steps 2 and 3 for the entire day. Plot the points at ONE HOUR intervals only.

3: Repeat this plotting of the Sun's daily motion on a clear day one month after the date of your original plot. Repeat this plotting for as many months as possible. Use a different color pen for each month.

4. Refer to an almanac or a calendar to determine the first day of each season. Plot the daily motion of the Sun on the hemisphere for these days. Use a different color pen for each day.

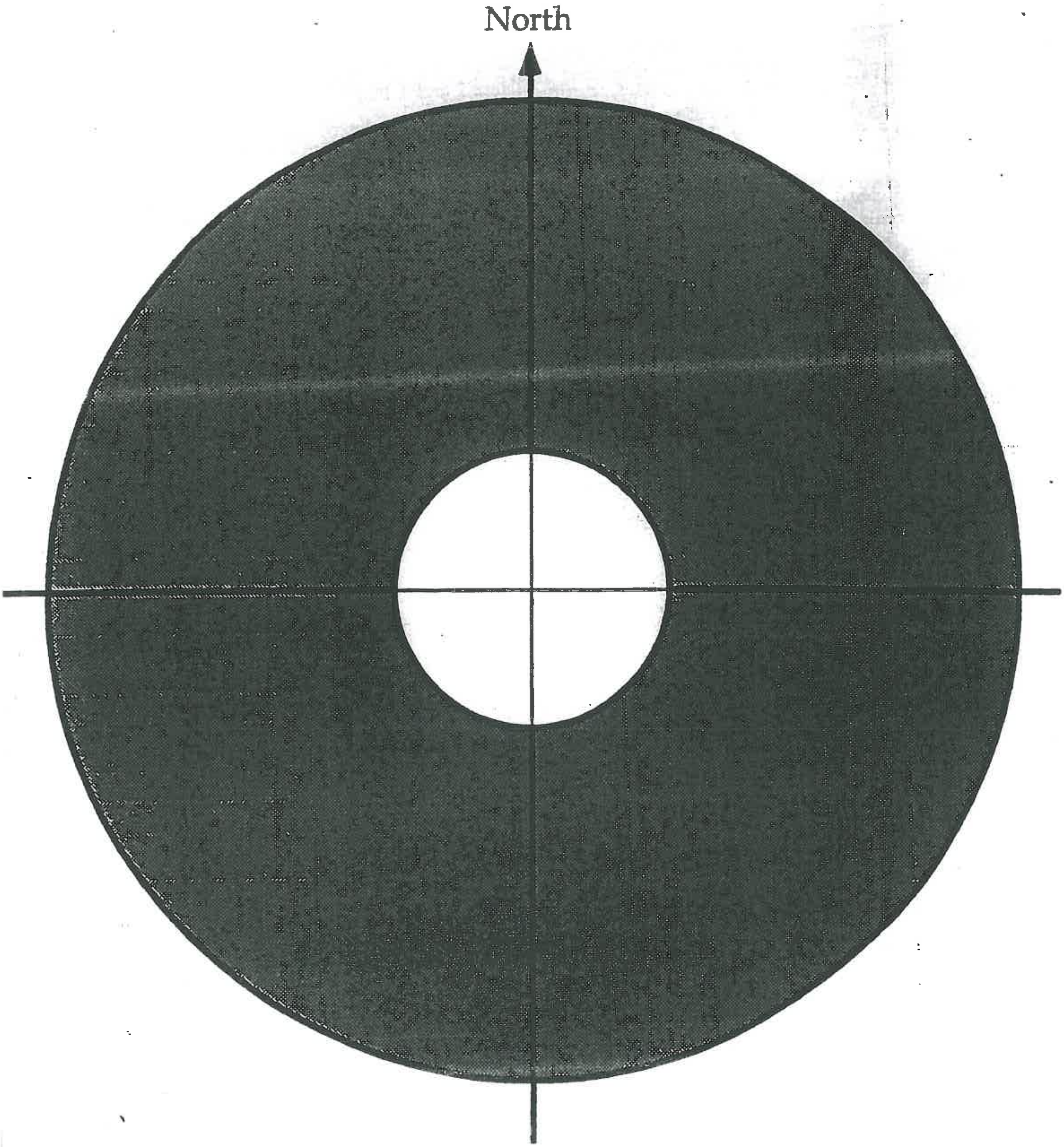



Figure 3.3 Hemisphere Base Diagram

## ACTIVITY 4 — BUILDING AND USING A CELESTIAL SPHERE

**PURPOSE**

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

## ACTIVITY 4A — BUILDING A CELESTIAL SPHERE

**MATERIALS**

2 plastic hemispheres
star chart sheet
heavy-duty wire cutters or pliers
colored marking pens (transparency pens work best)
Chart 4.1

protractor (the larger the better)
1 1-inch ball (or small Earth globe, if available)
1 sheet construction paper, 30 cm x 45 cm (12 in x 18 in)
6 paper clips

scissors
yellow-headed map pin
transparent tape
ruler
thumb tack
*dowel
*straw
* ( two new items added see sheet )

**PROCEDURE**

1. Cut out the two star charts with the scissors. Cut along the outside lines only. Each star chart will look like a flower with eight black petals.

2. Place the chart of the southern sky inside one of the plastic hemispheres with the printed side facing up. CAREFULLY align the chart so the ends of the Ecliptic (the line that crosses each of the chart's "petals") touch the base of the hemisphere at two opposite ridges. Secure the chart by placing the other hemisphere over the star chart and pushing it against the first hemisphere (see Figure 4.1). Make sure that the ridges of both hemispheres match.

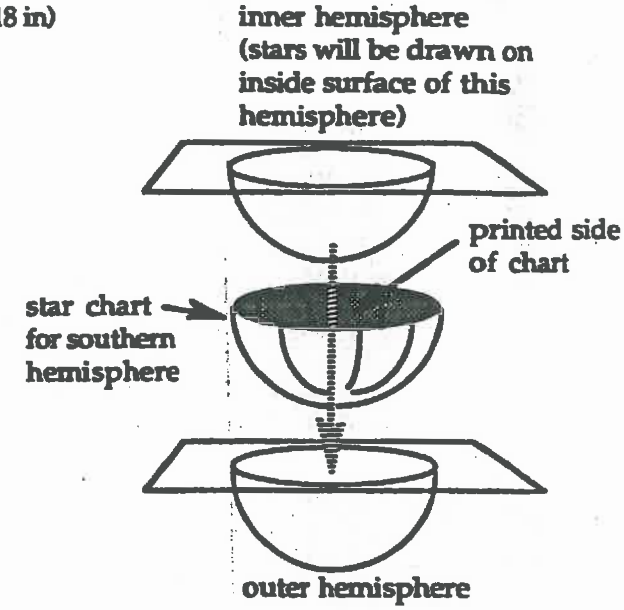



Figure 4.1

3. Show this "hemisphere/star chart sandwich" to your teacher before continuing to the next step.

4. Tape the edges of the two hemispheres together.

5. Mark the stars on the inside of the inner hemisphere with the marking pen. Also, draw the lines that mark the Ecliptic and some brighter constellations. (You may wish to use different color pens for the Ecliptic and the constellation lines.) The brighter stars are indicated by the bigger symbol. (The "magnitude" of a star is an indication of its brightness. A zero magnitude star is the brightest and the fourth magnitude star is the dimmest on this chart.)

6. When you have marked all the stars, separate the hemispheres and remove the star chart. Repeat Steps 2-5 with the northern star chart and the unmarked hemisphere (the "outer" hemisphere in Figure 4.1). Confirm that the Ecliptic lines touch the base at opposite ridges. Show the hemisphere "sandwich" to your teacher. (Use the hemisphere you have already marked to secure the chart in place.)

ADDITIONAL INSTRUCTIONS FOR THE PS-02 FOR THE ASSEMBLY PROCESS
( 9/23/91 )

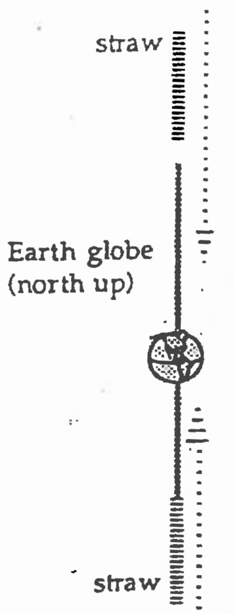


Figure 4

Slide the Earth globe to the center of the wooden dowel. Cut the drinking straw into two pieces, each 7.5-cm long. Slide these two pieces of straw over each end of the dowel. (Figure 4)

With the thumb tack, make a small hole through the center of both hemispheres (where the ridges cross). Slide the two star hemispheres onto the dowel with the southern hemisphere of the small Earth globe facing into the southern bowl of stars and the northern Earth globe hemisphere facing into the northern bowl of stars. (Figure 5)

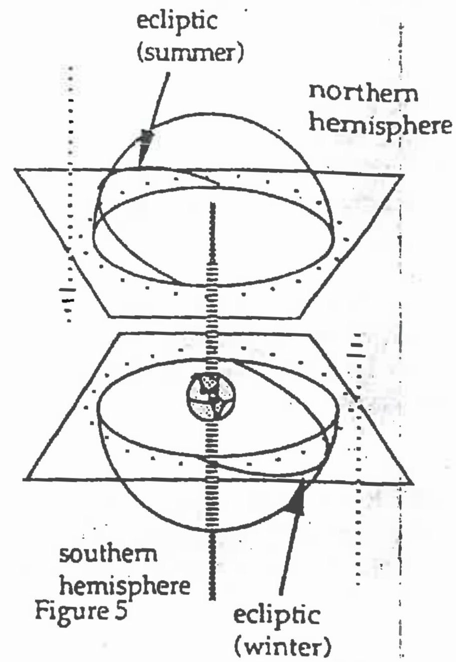


Figure 5

Rotate the hemispheres 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 .) The dimples on the northern hemisphere should match those on the southern hemisphere.

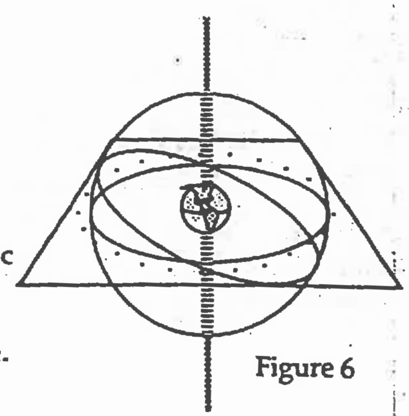
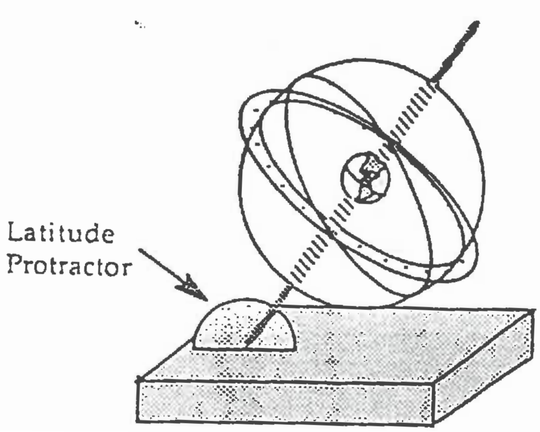
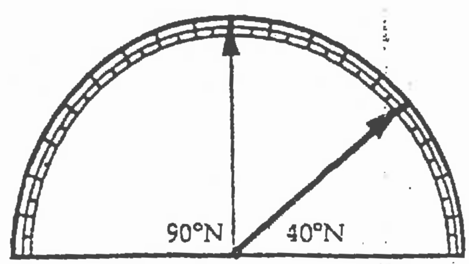


Figure 6

Note: Use the foam block to hold up the celestial sphere. Place the dowel into the foam block. See illustration.



Latitude Protractor

7. Look into the opening of the northern hemisphere (see Figure 4.2).

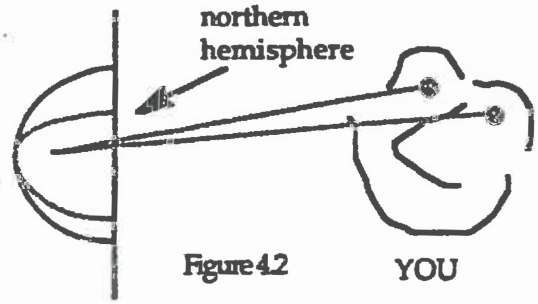



Figure 4.2

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

*4.2 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, the Big Dipper (an asterism - an easy to recognize pattern, not a constellation), and the northern half of Orion. The lined constellations on the southern hemisphere are Scorpius, Sagittarius, Canis Major, Alpha and Beta Centauri in the constellation Centaurus, the Southern Cross, and the southern half of Orion.

8. Cut out the two strips of dates on Chart 4.1. The strips should appear as shown in Figure 4.3. Tape the MAR to JUN to SEP strip into the northern hemisphere. The Ecliptic line on the hemisphere should pass through the center line of 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 into 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. Tape the strips in at least three places so when a pin is pushed through the plastic into the paper strip, the strip will not pop into the hemisphere.

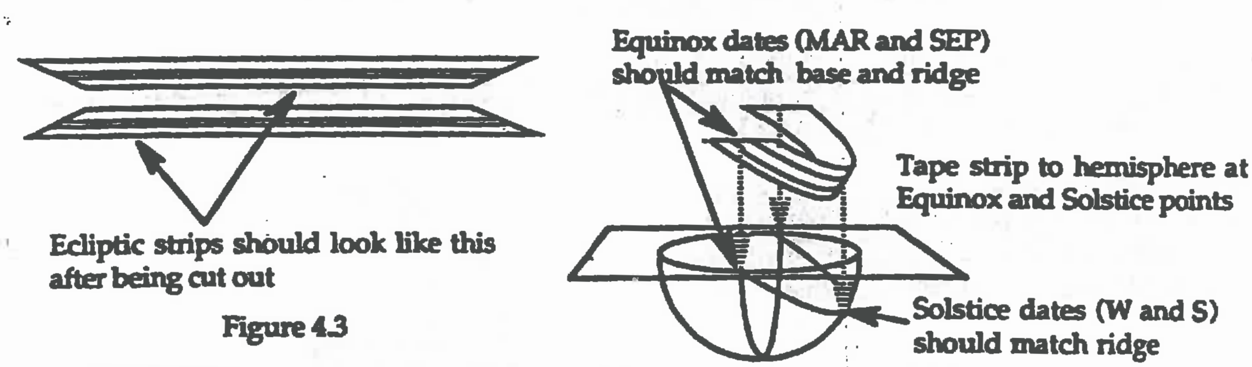



Figure 4.3

9. **BE VERY CAREFUL: the end of the hanger could puncture your eye or skin!** Cut off the hook portion of a wire coat hanger with wire cutters (or pliers) and discard. Do not straighten the entire wire. Bend a section of the hanger into the shape of a triangle so that it becomes the base of a stand, as shown in Figure 4.4.

10. With the thumb tack, make a small hole through the center of both hemispheres (where the ridges cross). Push the coat hanger wire through the hole in the southern hemisphere from the outside to the inside. Wrap a piece of tape around the wire about an inch up from the last bend in the wire. This tape will hold the southern hemisphere in place.

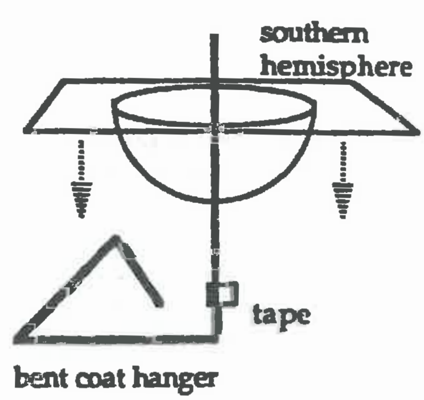



Figure 4.4

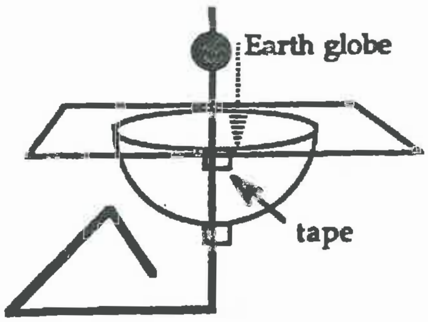



Figure 4.5

11. Slide the Earth globe onto the wire so the south pole faces the southern hemisphere. (If you use a Styrofoam ball, draw the Equator and poles.) See Figure 4.5. Line up the 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 south pole to hold the globe in place.

12. Push the wire through the celestial pole of the northern hemisphere with the opening of the hemisphere facing the opening of the southern hemisphere. See Figure 4.6.

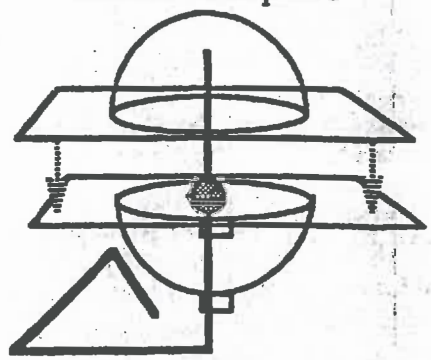



Figure 4.6

13. From a point about 1 inch above the northern hemisphere, bend the coat hanger wire about 90 degrees. Tape the end of the wire to prevent injury. See Figure 4.7.

14. Rotate the hemispheres 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 4.7.)

15. Tape the edges of your two spheres together. Trim the rim of the plastic sphere leaving the plastic bumps. With the hemispheres aligned as in Step 14, tape the spheres together. See Figure 4.7

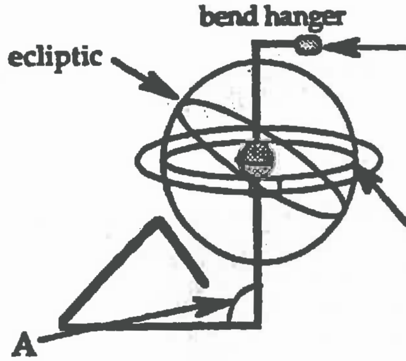



Figure 4.7

16. The clear plastic sphere should rotate freely on the wire; the Earth globe should be at the center of the sphere with North America facing up; and the northern hemisphere should be on the upper half of the sphere.

17. With the sphere standing on the table, bend the long part of the wire through the sphere so it tilts at an angle roughly equal to your latitude. With a protractor, measure the angle (A in Figure 4.7) this part of the wire makes with the table top.

18. Measure the height of the center of the Earth globe above the table top. Cut two strips of construction paper, each with a width equal to the height of the Earth globe above the table. Tape the pieces together to make a strip of paper 80 cm to 90 cm long. Cut these strips evenly!

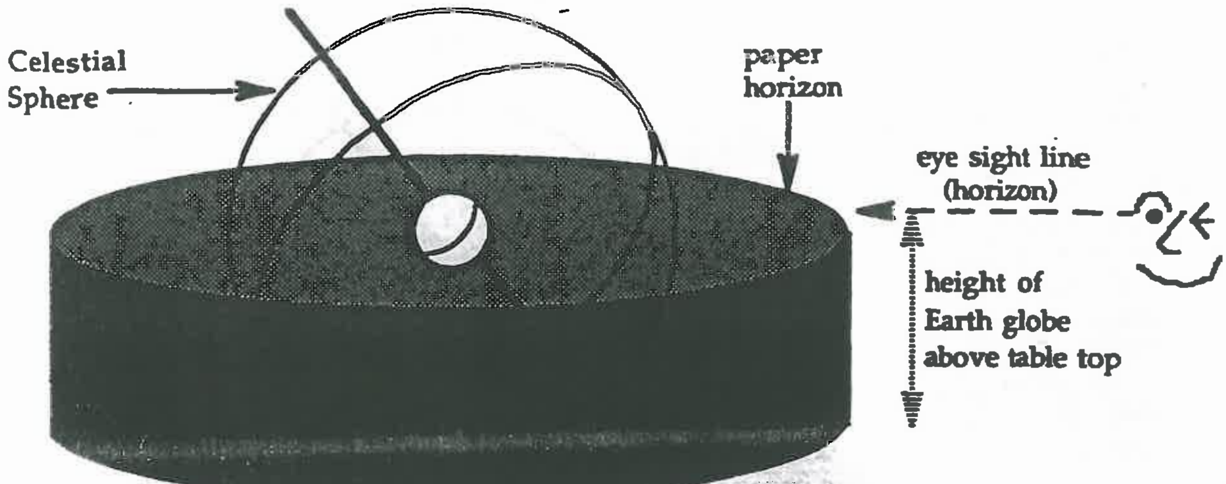



Figure 4.8

19. Refer to Figure 4.8. Connect the ends of the long strip together with paper clips to form a loop. The top edge of the construction 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 of the paper loop. Make any necessary adjustments of the paper clips to tighten the horizon around the sphere. The top edge of the loop, which represents the horizon, should be at the same height above the table as the center of the Earth globe.

20. On the upper, outside edge of the paper collar, at the point directly beneath where the wire touches the sphere, place an N, for North. On the paper horizon opposite N, place an S for South. Looking down on the horizon, go clockwise halfway from N to S. Mark this point E for East. Opposite E, place a W for West.

21. Save the yellow pin, paper horizon, and Celestial Sphere for later activities.

This Celestial Sphere will be used in this and a later activity to help you describe, explain and predict the motions of the Sun and the stars in the sky. Identify the following reference points and lines on your Celestial Sphere.

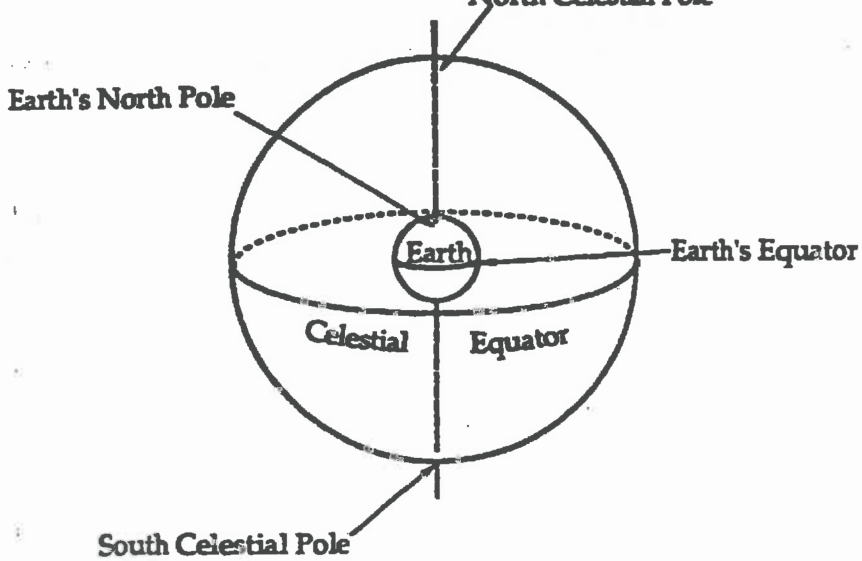



Figure 4.9

Refer to Figure 4.9. There are imaginary points such as the North and South Celestial Poles (N.C.P. and S.C.P.) and an imaginary line such as the Celestial Equator positioned on this sphere. The Earth is located at the sphere's center. Currently, the North Celestial Pole is very close to a star called Polaris.

Refer to Figure 4.10. 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. The highest point on the Ecliptic is called the Summer Solstice, and the lowest point is the Winter Solstice. As the sun appears to move across the sky, it passes through a band of constellations known as the Zodiac.

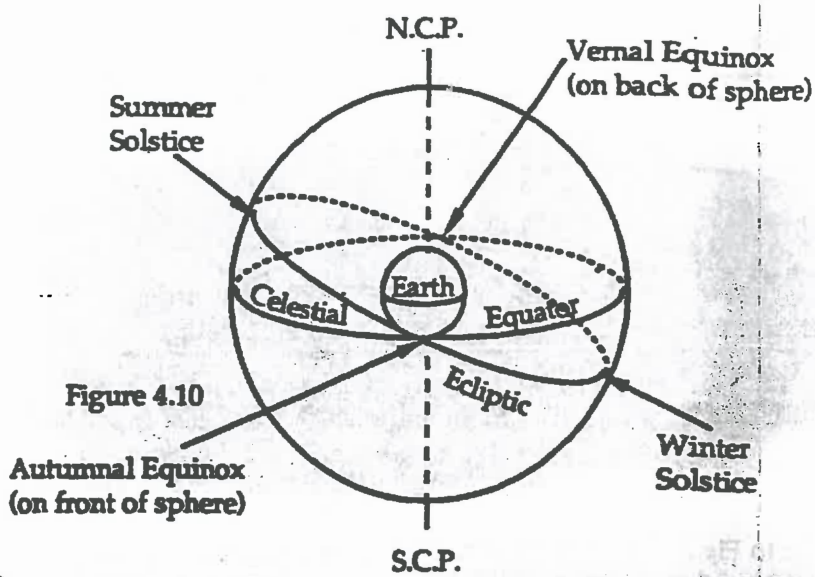



Figure 4.10

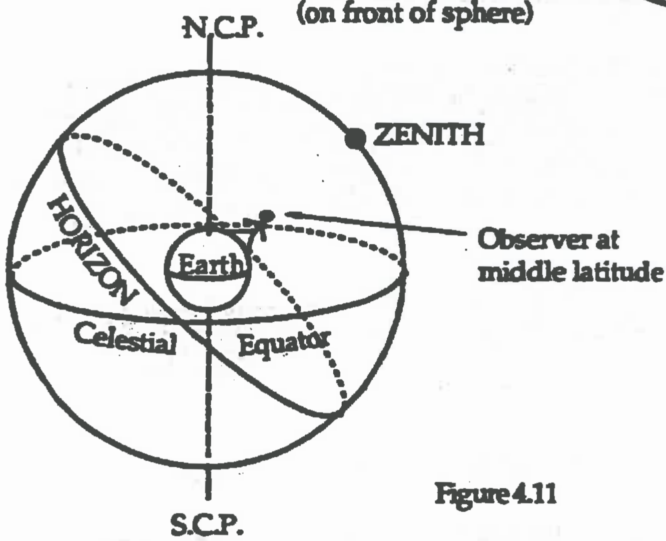



Figure 4.11

Refer to Figure 4.11. The point directly over the head of the observer is called the Zenith. The Horizon is located 90° in every direction away from the observer's zenith. 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 the sky "meets" the land or water.

Figures 4.9, 4.10, and 4.11 are related to the Celestial Sphere that you have just built. The hanger wire that passes through the globe is the vertical dashed line in Figures 4.9, 4.10, and 4.11. 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 by the arcs drawn on the inside of each hemisphere.

## ACTIVITY 4B MODELING THE SUN'S DAILY MOTION

### MATERIALS

Celestial Sphere with accessories from ACTIVITY 4A
plastic hemisphere with observations from ACTIVITY 3
pin (for Sun marker)

### PROCEDURE

**Write the answers to questions and/or problems in the spaces provided.**

1. On the Ecliptic, locate the date that you made the observation in ACTIVITY 3. Stick the pin into your Celestial Sphere at this date.

2. Place the horizon collar around the Celestial Sphere. Be sure the collar's North point is properly aligned with the sphere's axis. Rotate the sphere and collar together until "South" on the collar faces you.

3. 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 level with the top of the right side of the collar. This is the sunrise position for the date from ACTIVITY 3.

4. Slowly rotate the sphere from East to West (clockwise, as viewed from above the North Celestial Pole) and watch the motion of the pin. When the pin is level with the top of the collar, it is at the sunset position.

The Celestial Sphere is a model of the sky. Turning the sphere on its axis represents the Earth turning on its axis. One complete rotation of the sphere, therefore, corresponds to 24 hours. There are 24 bumps on the flat surfaces at the sphere's equator, each indicating one hour of time.

4.3 *Turn the sphere to move the Sun marker from sunrise to sunset. Count bumps that pass the western horizon. This is the number of hours of daylight for the day in ACTIVITY 3.*

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

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

*c) From a newspaper, or other source, obtain the actual daylight period for the date you did ACTIVITY 3. How did the actual time compare with the sphere time?*

4.4 *Compare the path of the Sun as demonstrated with your Celestial Sphere to the path you plotted on the hemisphere in ACTIVITY 3.*

4.5 *Set the Celestial Sphere for two hours after sunset for this date.*
*(a) Name a constellation in the southern sky.*

*(b) Name a constellation near the zenith.*

*(c) Describe the position of the Big Dipper in the sky.*

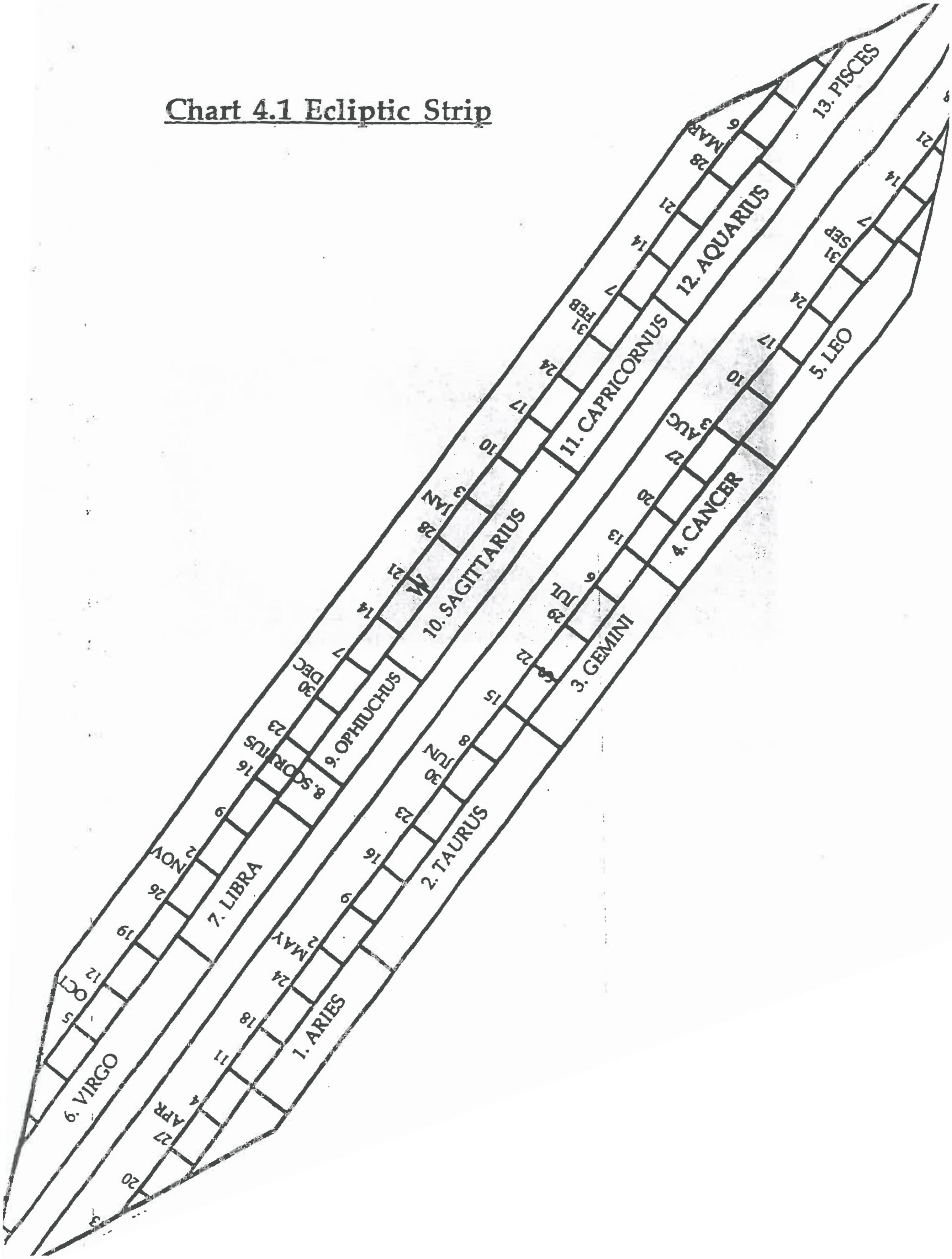
*(d) Name a constellation that is just rising. Specify the direction where it is rising.*

*(e) Name a constellation that is below the horizon and cannot be seen at this time.*

## EXTENSIONS

1. Plot the apparent motion of the Sun for an entire school day on one student's hemisphere.
2. Plot the apparent daily motion of the Sun on other days through the school year and use the Celestial Sphere to explain these apparent motions of the Sun.

## Chart 4.1 Ecliptic Strip



## ACTIVITY 6 MODELING THE REASONS FOR THE SEASONS

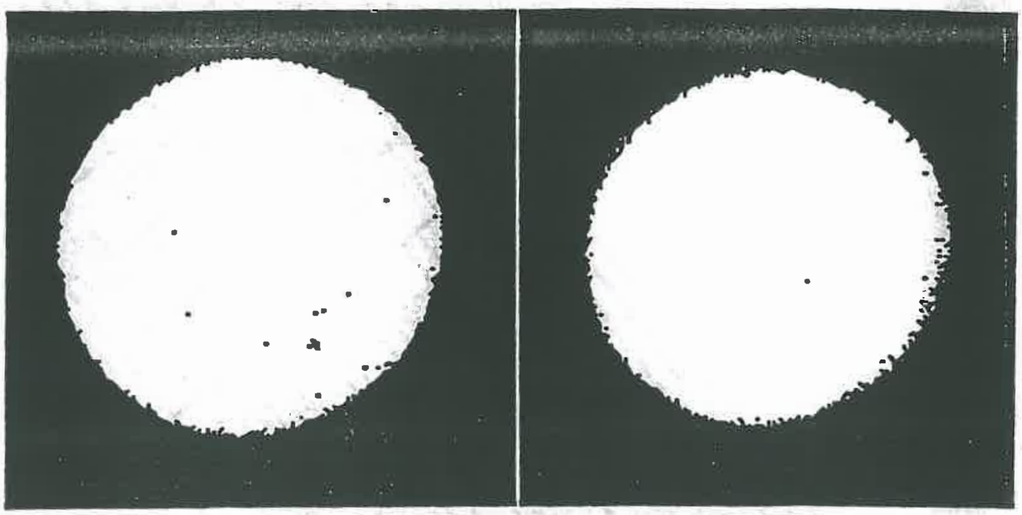
### PURPOSE

To plot the distance of the Earth from the Sun over one year and to use the Celestial Sphere to show the cause of the seasons.

### WHAT DO YOU THINK?

Write answers to questions and/or problems in the spaces provided.

Figure 6.1 shows two pictures of the Sun taken six months apart with the same camera, at the same time of day, from the same location.



Month? ____________________ Month? ____________________

Figure 6.1

**6.1** *Are the images of the Sun the same size?*

**6.2** *If they are not the same size, how could you explain the difference?*

**6.3** *Below each image write the month in which you think it was photographed.*

**6.4** *What month or months of the year is your weather the warmest?*

## ACTIVITY 6A ___ PLOTTING THE DISTANCE FROM THE EARTH TO THE SUN

**MATERIALS**

metric ruler
Chart 6.1
Graph 6.1
calculator
felt-tip marker or pen

**PROCEDURE**

1. Look at the photos on Chart 6.1 (these photos were published as Plate IX in "Paths of the Planets" by R.A.R. Tricker). Each photo is a section taken through the middle of the Sun from a larger picture. See Figure 6.2.

2. Measure the length of the dark portion of each photo to the nearest tenth of a centimeter and record your measurement in the space in the column to the left of each photo.

3. For the specific date each photograph was taken, calculate the distance to the Sun by dividing 1,750,000,000 kilometers-centimeter by the length (in centimeters) of each solar photograph. (Use 1,075,000,000 mi-cm if you wish to calculate the distance in miles.)

4. Record the distance to the Sun corresponding to each measured diameter in the space in the column to the right of each photo.

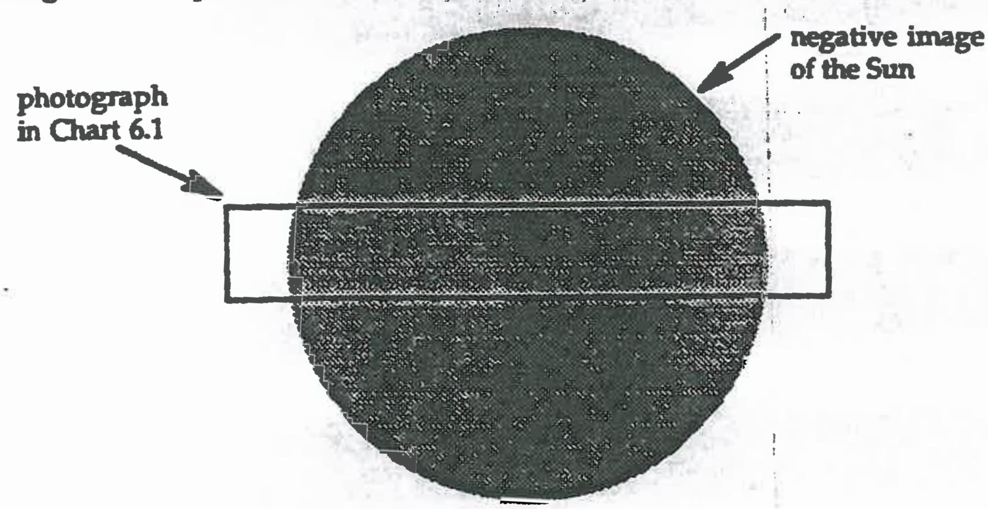


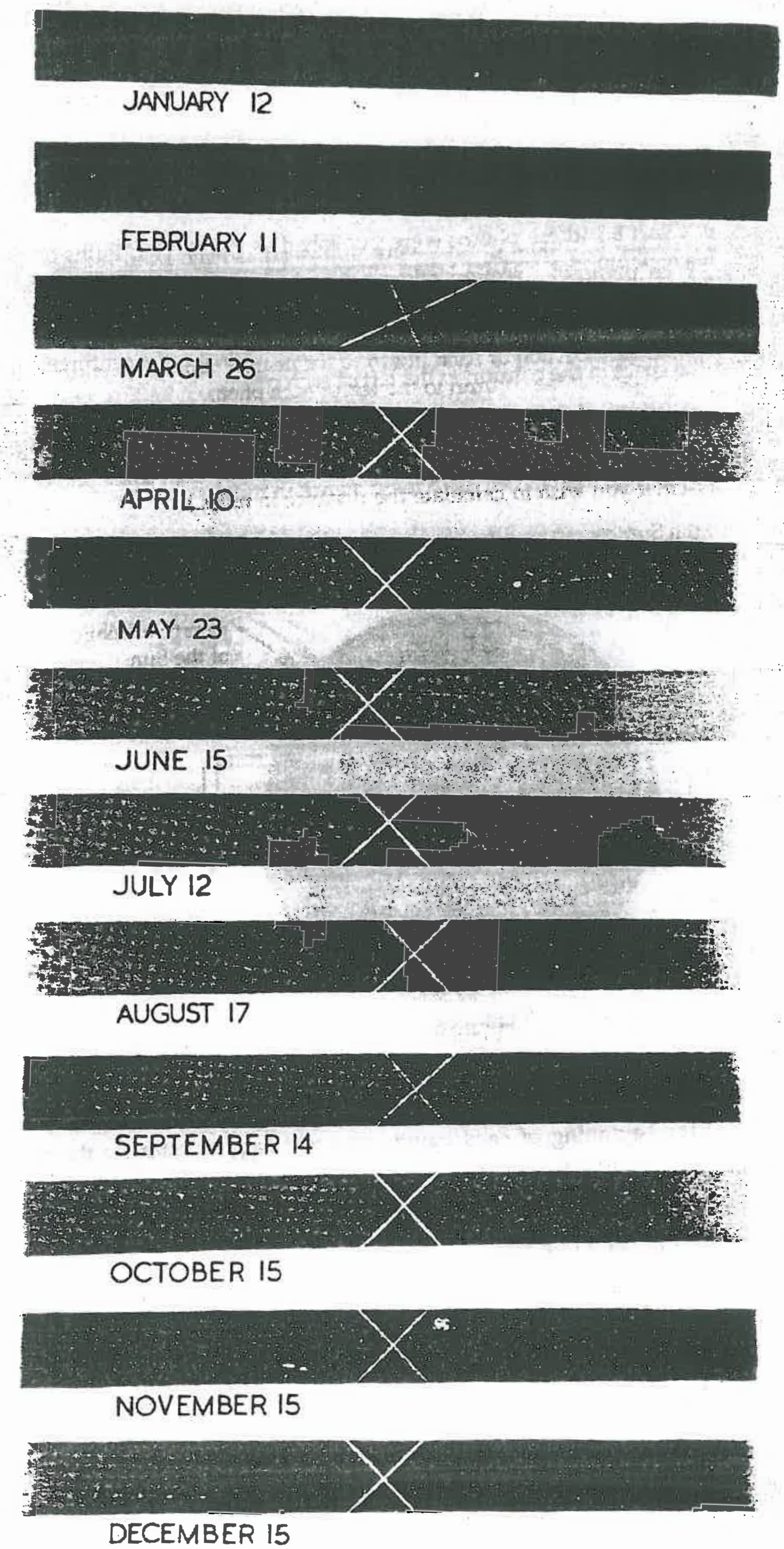

Figure 6.2

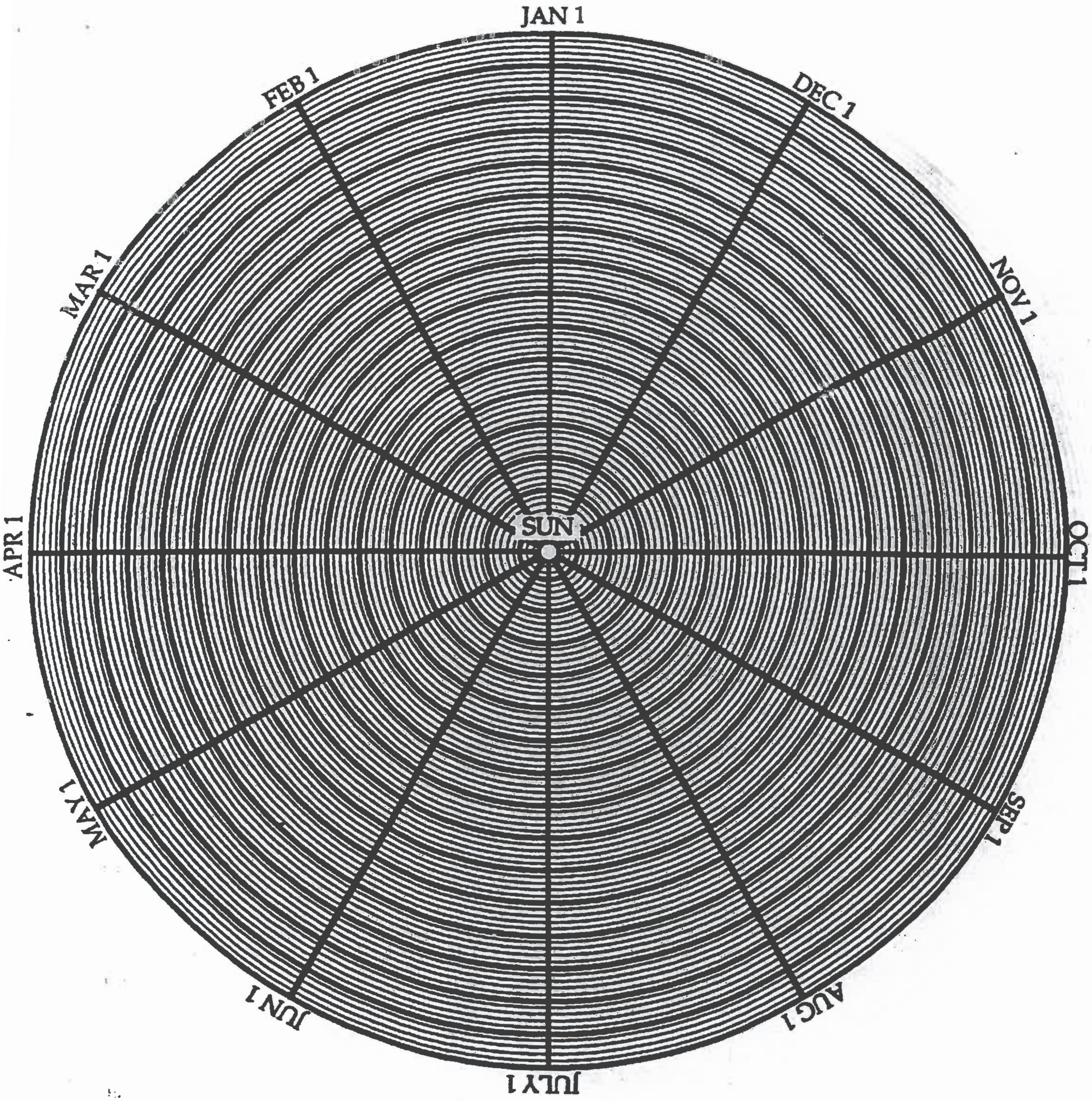
5. Plot the distance of the Earth from the Sun for each date on Graph 6.1. Because the dates of the photographs are not at the beginning of each month, you will have to estimate the position for each date on the graph.

6. Connect the points on the graph with a smooth curve. Use a pencil first, then trace over this penciled curve with a felt-tip marker or pen.

# CHART 6.1
## SOLAR IMAGE CROSS-SECTIONS

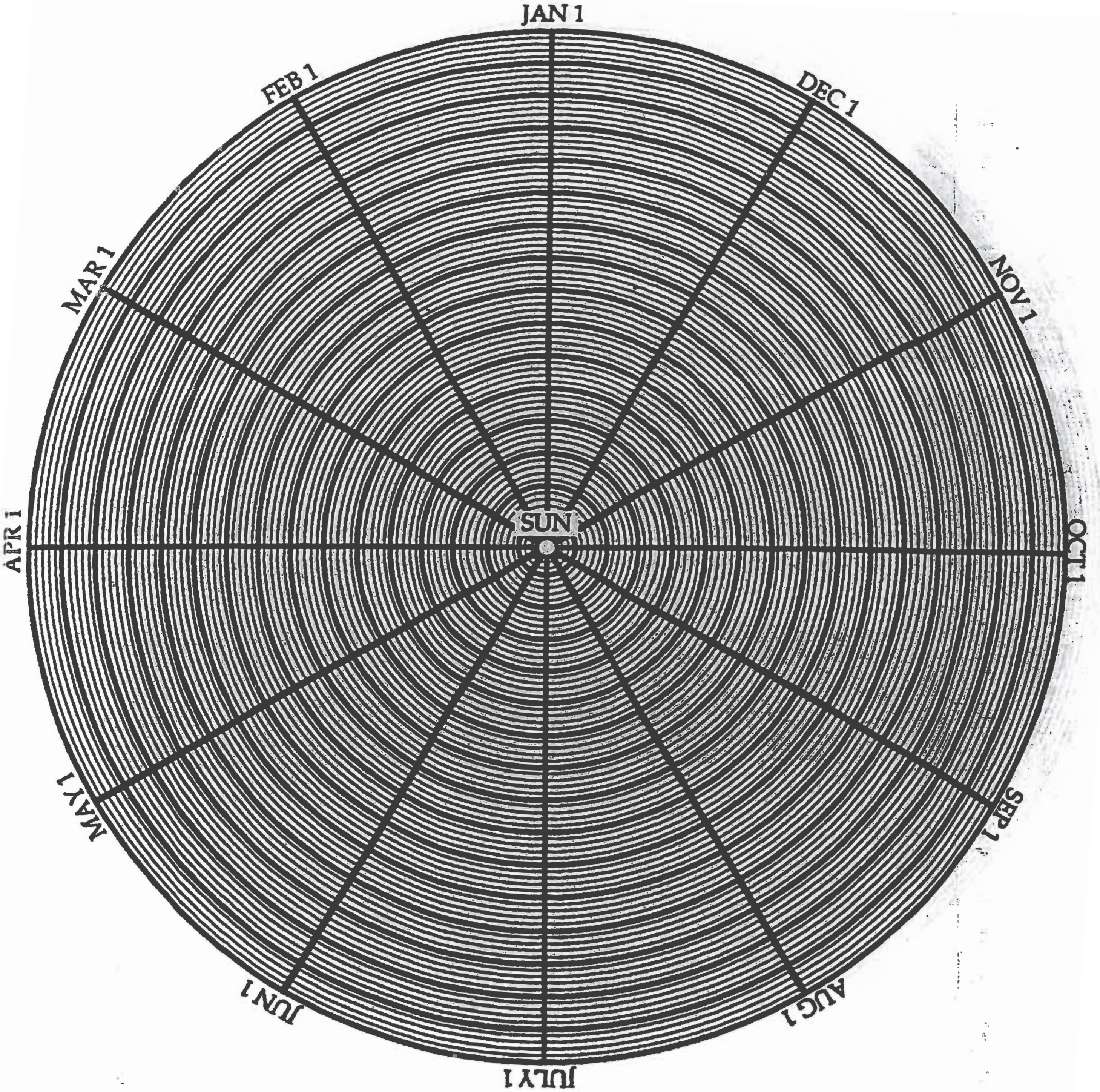
calculated distance from Earth to Sun






**Graph 6.1 EARTH-SUN DISTANCE FOR ONE YEAR**

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




**Graph 6.1 EARTH-SUN DISTANCE FOR ONE YEAR**

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

*6.5 What does this curve represent about the Earth?*

*6.6 In what month is the Earth farthest from the Sun?*

*6.7 In what month is the Earth closest to the Sun?*

*6.8 Compare the answers from the two previous questions to your predictions in Figure 6.1.*

From your measurements, calculations (Step 3) and graph 6.1, answer the following questions.

*6.9 Describe what your graph shows.*

*6.10 What conclusions can you draw from the observation that the Sun has a different apparent size in the Summer than in the Winter?*

*6.11 Compare the months of your warmest weather to the month when the Earth is closest to the Sun.*

## ACTIVITY 6B ___ MODELING THE SUN'S MOTION ON THE CELESTIAL SPHERE

**MATERIALS**

Celestial Sphere with accessories
journal from ACTIVITY 1
protractor

**PROCEDURE**

Write answers to questions and/or problems in the spaces provided.

Figure 6.3 shows the side view of the Celestial Sphere at the Summer Solstice as seen from a latitude of 42 degrees North. Using this figure as a sample, position your Celestial Sphere and horizon collar to correspond with your home latitude.

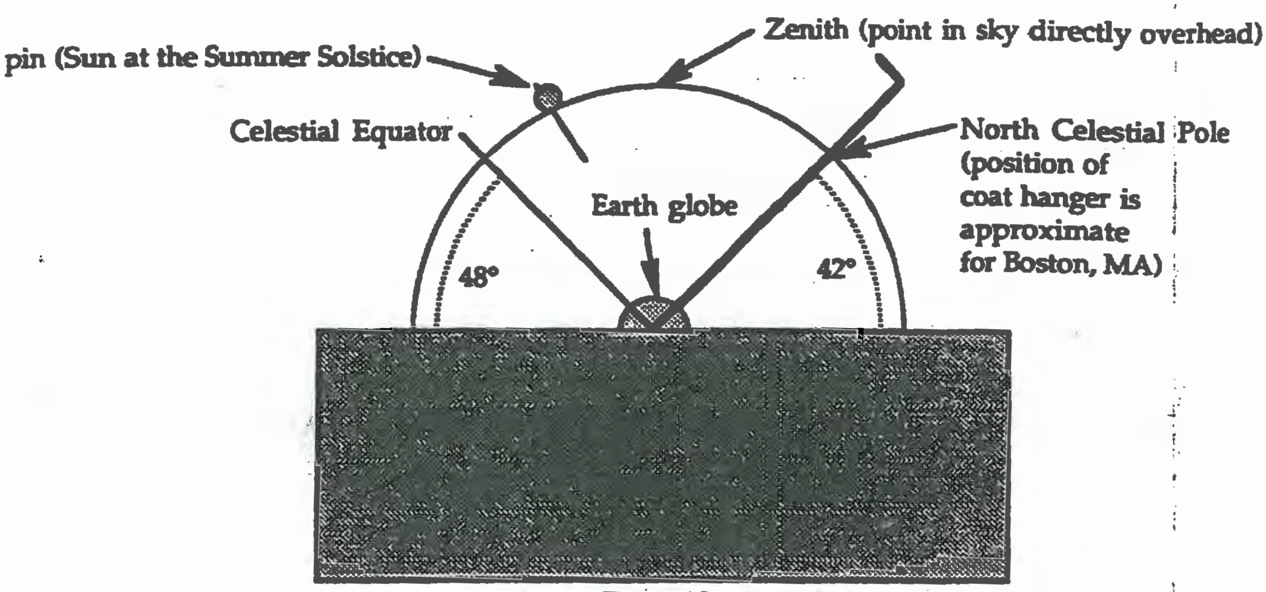



Figure 6.3

1. Bend the coat hanger so the Celestial Sphere is set for your local latitude. For stability, tape the base of the sphere's stand to the top of the table.

2. When drawing, always observe the Celestial Sphere with your eyes at the level of the Earth globe and the top edge of the paper horizon. Place North to your right. To answer Questions 6.12 - 6.35, refer to the following instructions and Figure 6.3. Draw on Figures 6.4 to 6.7.

   a) Draw the coat hanger as you see it. Indicate the North Celestial Pole and the Horizon.

   b) Starting from the right hand side of the collar in the figure, measure the angle between the N.C.P. and the northern horizon. This angle is equal to your latitude. Place the protractor with the vertex of the angle at the center of the Earth globe on the diagram.

   c) Draw in the Celestial Equator. This line forms a 90° angle with the North Celestial Pole.

   d) Measure the remaining angle between the Celestial Equator and the paper collar horizon. Label this angle on the diagram.

   e) Draw the position of the Sun above the horizon at noon on June 22. Label this position as the Summer Solstice.

3. Position the Sun marker on the Ecliptic line of the Celestial Sphere at the point of the Summer Solstice, June 22. Be sure the compass points of the horizon's collar are properly lined up with the sphere. Viewing horizontally at the same height as the top of the collar, set the Sun marker even with the top edge of the East side of the horizon collar. This position corresponds to sunrise. Turn the sphere clockwise (as viewed from overhead) until the Sun is level with the horizon on the other side of the collar. This movement represents the apparent motion of the Sun from sunrise to sunset on June 22.

*6.12 What was the general direction of sunrise?*

*6.13 What was the general direction of sunset?*

*6.14 Turn the sphere to move the Sun marker from sunrise to sunset. Count the number of bumps that pass the western horizon. This number represents the hours of daylight. How many hours of daylight are there on June 22?*

*6.15 Figure 6.4 represents a side view of your Celestial Sphere. On the figure, draw and label the approximate position of the Celestial Equator, North Celestial Pole, and the Sun's position above the horizon at noon on June 22. (Noon occurs when the Sun is halfway between its rising and setting positions or when the Sun is at its highest point in the sky for that day.)*

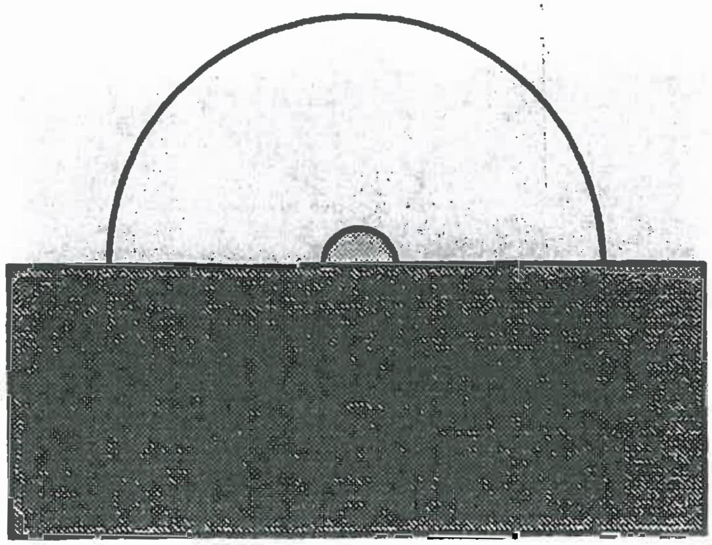


Figure 6.4

*6.16 What pattern of stars will be close to zenith just after sunset?*

*6.17 What pattern is close to zenith at 1 a.m.?*

Place the Sun on the Ecliptic at the Autumnal Equinox, September 21. Set the Sun marker even with the top edge of the East side of the horizon collar when viewed horizontally. Turn the sphere clockwise until the Sun is level with the horizon on the other side of the collar. This movement represents the apparent motion of the Sun from sunrise to sunset on September 21.

*6.18 What was the general direction of sunrise?*

*6.19 What was the general direction of sunset?*

*6.20 How many hours of daylight are there on September 21?*

*6.21 On the diagram below, draw and label the position of the Celestial Equator, the North Celestial Pole, and the Sun at noon on September 21. Label the Sun's position as the Autumnal Equinox.*

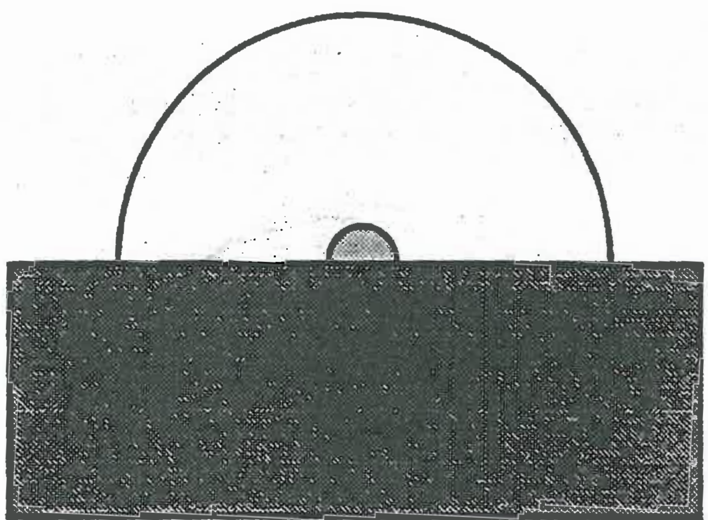


Figure 6.5

*6.22 What constellations are visible close to the southern horizon just after sunset?*

*6.23 Describe the location of Cygnus in the sky just after sunset.*

5. Place the Sun on the Ecliptic at the Winter Solstice, December 21. Set the Sun marker even with the top edge of the East side of the horizon collar when viewed horizontally. Turn the sphere clockwise until the Sun is level with the horizon on the other side of the collar. This movement represents the apparent motion of the Sun from sunrise to sunset on December 21.

*6.24 What was the general direction of sunrise?*

*6.25 What was the general direction of sunset?*

*6.26 How many hours of daylight are there on December 21?*

*6.27 On the diagram below, draw and label the position of the Celestial Equator, the North Celestial Pole, and the Sun at noon on December 21. Label the Sun's position as the Winter Solstice.*

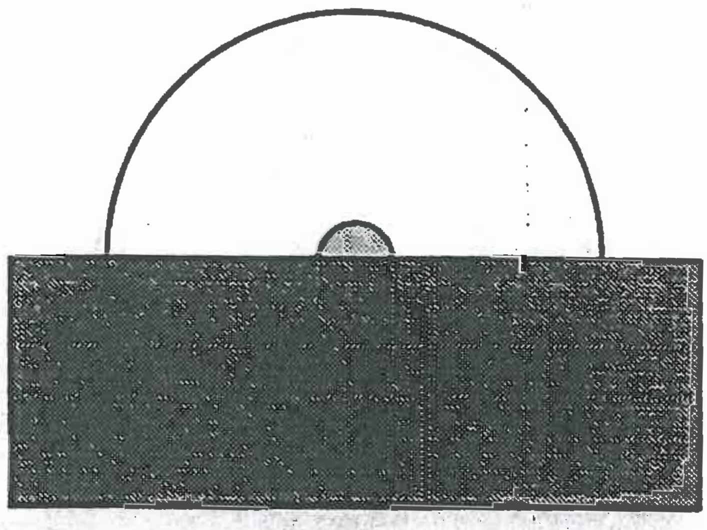


Figure 6.6

*6.28 What constellations will be rising from the East just after sunset?*

*6.29 What constellation will just be setting in the Northwest about 9 p.m.?*

6. Place the Sun on the Ecliptic at the Vernal Equinox, March 20. Set the Sun marker even with the top edge of the East side of the horizon collar when viewed horizontally. Turn the sphere clockwise, until the Sun is level with the horizon on the other side of the collar. This movement represents the apparent motion of the Sun from sunrise to sunset on March 20.

*6.30 What was the general direction of the sunrise?*

*6.31 What was the general direction of the sunset?*

*6.32 How many hours of daylight are there on March 20?*

*6.33 On the diagram below, draw and label the position of the Celestial Equator, the North Celestial Pole, and the Sun at noon on March 20. Label the Sun's position as the Vernal Equinox.*

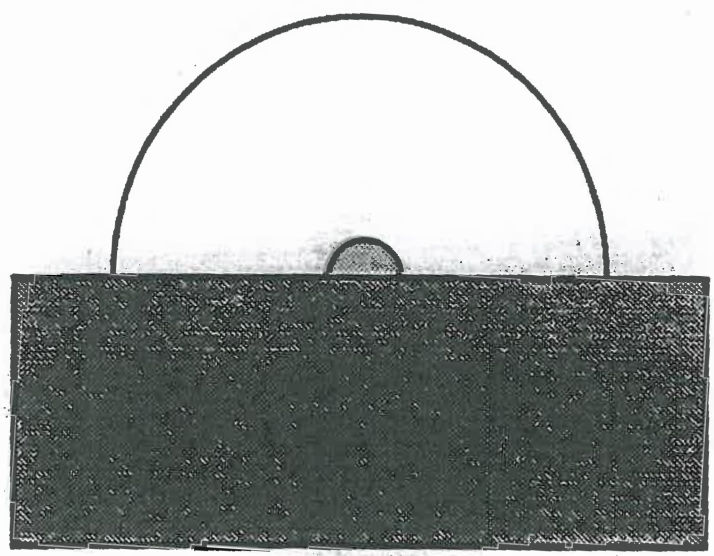


Figure 6.7

*6.34 Describe the location of Orion in the sky just after sunset.*

*6.35 What constellation is high in the southern sky at 9 p.m.?*

## DISCUSSION QUESTIONS

6.36 a) Does the Sun always rise exactly from the East ?

b) List the directions of sunrise at the beginning of each season.

Summer: Winter:

Autumn: Spring:

6.37 a) Does the Sun always set exactly in the West?

b) List the directions of sunset at the beginning of each season.

Summer: Winter:

Autumn: Spring:

6.38 Compare the results from this activity with the data you collected in the Sunset Journal (from ACTIVITY 1).

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

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

c) Use your Celestial Sphere to predict how your sunset journal would look for the next three months. Draw your predictions on a separate sheet of paper.

6.39 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?

6.40 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 ?

6.41 *Describe the changes in the noon position of the Sun from:*
*a) Summer Solstice to Autumnal Equinox.*

*b) Autumnal Equinox to Winter Solstice.*

*c) Winter Solstice to Vernal Equinox.*

*d) Vernal Equinox to Summer Solstice.*

6.42 *Was the Sun ever directly overhead at noon for your location?*
*If so, on what date(s)?*

6.43 *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.*

6.44 *Describe the location in the sky of the constellation Orion at sunset for the beginning of each season.*

*Summer:*

*Winter:*

*Autumn:*

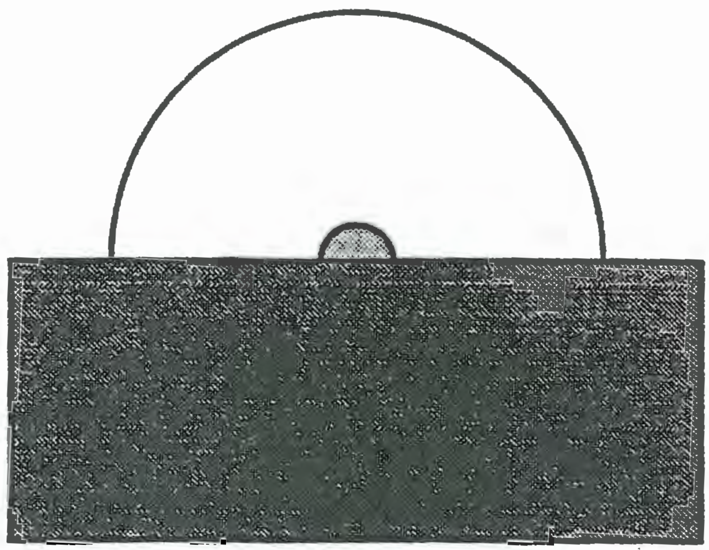
*Spring:*

## QUESTIONS TO TEST YOURSELF

1. If the Sun sets in the Northwest, what season is it?

2. If the Sun sets in the Northwest, from what direction did it rise on that day?

3. On the sphere below, draw the Celestial Equator and the North Celestial Pole for your location on Earth. Mark and label the positions for the Sun's noon locations for both of the Equinoxes and the Solstices.



(a) Put an X at the position of the Sun at noon on November 23.

(b) How many hours of daylight are there on November 23?

(c) Where in the sky would the constellation Sagittarius be found at sunset on November 23?

4. Is it hotter in the summer than in the winter because we are closer to the Sun in June than we are in December? Explain.

5. What day of the year would the constellation of Cygnus be rising at sunset?

6. Describe the motion of the Big Dipper and Cassiopeia in the sky during a 24-hour period.

## EXTENSIONS

1. Research and write about how open-air athletic stadiums are designed to account for the changing position of the daytime Sun for various seasons of the year.

2. Research and write about passive solar houses and buildings.

3. Research and write about how various technologies can and are being used to harness solar energy.