

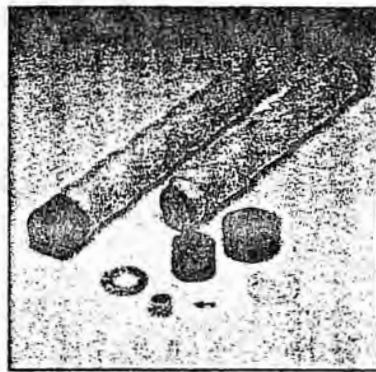
ASTRONOMICAL INSTRUMENT KIT FOR COLLEGE ASTRONOMY

MANUAL

#PS-13



CELESTIAL SPHERE



16X REFRACTING TELESCOPE



SPECTROMETER

THE COLLEGE ASTRONOMY KIT

This kit contains three projects that will complement an introductory astronomy course at the college level. Each project consists of a device that you build and then use with some activities.

1. Simple Astronomical Telescope

You will experiment with lenses to discover how the parts of the telescope work and then place them in tubes to make a 16X astronomical telescope and make observations of terrestrial and celestial objects.

2. Spectroscope

You will experiment with a diffraction grating to see how it breaks up light and then assemble it into a simple spectroscope to observe the spectra of everyday light sources including the Sun.

3. Celestial Sphere

You will construct a version of the one of the oldest astronomical devices to make a model of how the Sun and the stars appear in the sky for different seasons of the year as seen from different places on the Earth.

The packages that contain the parts also contain the instructions for building the instrument. It is recommended that you build the telescope and spectroscope first. You will need the box in which the material was shipped for the celestial sphere.

NOTE: The activities for the telescope and spectrometer pause before assembly's complete. Therefore, read through the beginning of each activity before starting construction. Full directions for assembly are in Notes 1, 2, and 3.

You will have to supply the following materials for successful construction of the instruments in the kit:

pair of scissors (comfortable)
ruler (metric and English)
colored pencils or pens (or crayons)
notebook (with paper...lined or unlined)

Work carefully and take the time to perform all of the activities and write the answers to all of the questions. These devices and the activities should help you understand and appreciate some of the concepts covered in your introductory astronomy course.

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THE ASTRONOMICAL TELESCOPE - CLOSE UP OF THE UNIVERSEActivity 1

For thousands of years, people looked at the sky with their eyes and made pictures out of the star patterns. They learned to build simple instruments that measured and tracked the position of the stars and the sun in the sky. This information was used to determine their position on the Earth's surface. In the 1600's, an Italian scientist, Galileo Galilei, used ground simple lenses to build what was first used as a military device and then used to take a close look at objects in the sky. These first looks changed the way people viewed the universe forever. In this activity you will build a telescope similar to the one Galileo made and use it to make some of the same observations.

FUNCTIONS OF THE LENS

Before you build the telescope, first play with the parts that make the telescope work. You will investigate two properties of lenses: focal length and magnification. Both of these properties can be used to describe inward curving (concave) mirrors, which are also used in astronomical telescopes. By way of definition: **FOCAL LENGTH** is the distance behind a lens that an image will form of a very, very distant object; **MAGNIFICATION** is the ability of a lens to make an object look larger than when viewed only by your naked eye.

The purpose of the first two parts of this activity is to estimate the focal length of both lenses in the kit and how the lenses can be used as simple magnifiers. Also, the term "ASTRONOMICAL TELESCOPE" is being stressed because it behaves differently than a normal "spy glass", or terrestrial telescope (as you will see).

MATERIALS (from the kit)

- 1 large plastic lens
- 1 small plastic lens

FOCAL LENGTH OF A LENS

1. Locate a lamp in a room. Stand next to a plain wall on one side of the room with no obstructions between the wall and the lens. Hold the lens with its diameter as flat to the wall as possible and against the wall. Slowly pull the lens away from the wall until the image of the lamp on the wall is clear and crisp. (Figure 1)

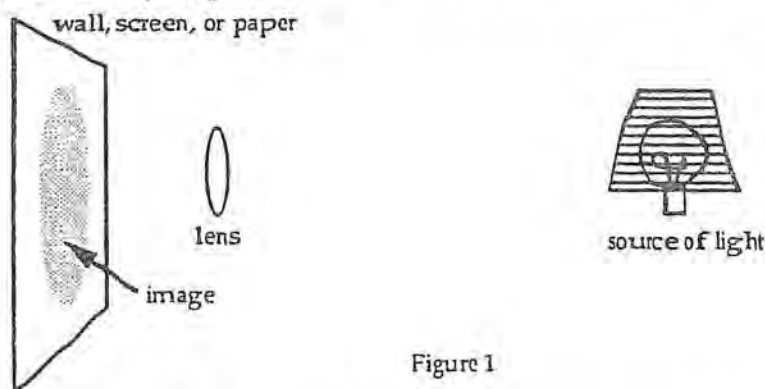


Figure 1

- a) Describe the image of the lamp on the wall.
Is the image erect (right-side-up) or inverted (up-side-down)? Is the image of the lamp bigger or smaller than the lamp?
- b) How many centimeters is the lens from the wall?

2. During the daytime, go to a room that has an outside window. Locate a distant (a mile or two or more away) object that is silhouetted against the sky (try a bright moon at night). Move the lens away from the wall until a clear and crisp image of the distant object is formed.

a) Describe the image of the distant object on the wall:

Is the image erect or inverted? Is the image bigger or smaller than the object?

b) How many centimeters is the lens from the wall?

c) Is this longer or shorter than the distance in 1b)?

3. Try the same procedure with a planet or some stars in the night sky.

a) Describe what you observe:

(Did it work?)

The images of more distant objects get closer to the focal point, or focus, of the lens. The distance of the focus from the lens is the **FOCAL LENGTH** of the lens. The distance between the lens and an image of the distant object is approximately the focal length of the lens.
What is the focal length of the large lens?

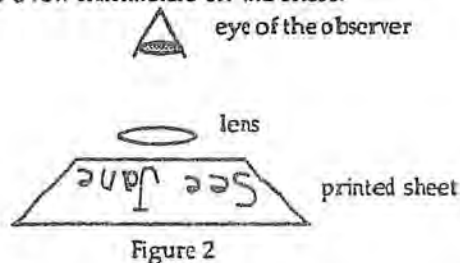
4. Repeat steps 1 and 2 with the smaller lens.

a) Describe anything you notice different about the images and distances for the small lens;

b) What is the focal length of the small lens?

SIMPLE MAGNIFIER

5. Lay the large lens on top of a printed page as shown in Figure 2. Your face should be about 1 meter from the paper. Lift the lens a few millimeters off the sheet.



a) Describe the image of the print as seen through the lens:

Is the image erect or inverted? Does the image appear bigger or smaller than the object?

6. Move the lens away from the paper toward your eye. It will be better if one eye is closed.

a) Describe what happens to the image:

7. Now lay the small lens on the paper. Your face should be about 1 meter from the paper. Lift the lens a few millimeters off the sheet.

a) Describe the image of the print as seen through the lens:

Is the image erect or inverted? Does the image appear bigger or smaller than the object?

8. Slowly lift the lens off the paper closer to your eye.
 - a) Describe what happens to the image:
9. Which produces the larger image, the large lens or the small lens?
10. Position the small lens so you get the largest and clearest image. Measure the distance of the lens above the sheet.
 - a) What is the distance?
 - b) How does this compare to the focal length of that lens? (Is it longer or shorter?)
11. Now make an "air telescope". Hold the large lens at arms length. View some distant object through the lens. Then move the small lens close to your eye. Align the lens so you are looking through both at the same object. Adjust the position of the small lens (and adjust the focusing of your eye until you see a magnified image of the distant object). You will need to concentrate on the image you see through the small lens.
 - a) Describe the image:

This is the basic operation of a simple telescope. The large lens (long focal length) collects the light from a distant object and forms a small image of it near the focal point. The eyepiece lens (short focal length) then acts as a simple magnifier to enlarge this small image. The remainder of this activity is the construction of a device for holding the lenses more efficiently and conveniently.

USING AN ASTRONOMICAL TELESCOPE

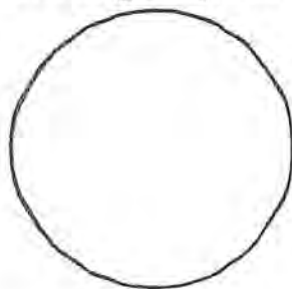
Build your astronomical telescope using the directions in Note 1.

MATERIALS

telescope
objects from your local universe

PROCEDURE

1. Observe a terrestrial object such as a large advertising sign or the leaves or branches in a tree. Draw the image that you see in the circle below and make any comments that come to mind:



COMMENTS:

2. Take the plastic cap off the objective end of the telescope. **BE CAREFUL NOT TO DROP THE LENS!!!** Remove the cardboard washer and replace the plastic cap.
3. Look at the same sign as you did in step 1. Describe any difference you see from the observations in step 1.

The image should appear clearer. The edges of the lens act like a prism making colors focus at different distances behind the lens. Covering the outer part of the lens decreases this effect producing a clearer image.

IMPORTANT SUGGESTION!!!!

Magnifying objects also magnifies motion. To prevent vibration, secure your telescope with rubber bands or tape to some object or hold it snugly against a post or a tree. You might even want to try to invent a method of attaching it to a camera tripod.

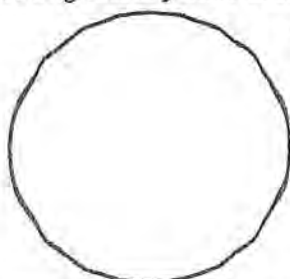
NEVER LOOK AT THE SUN THROUGH THIS TELESCOPE!

Now use the telescope to make some observations, similar to those made by Galileo in 1610. Always indicate the date, time, and viewing conditions for any observation. Draw what you see through the telescope in the circle provided. This circle represents the field of view of the telescope. Do not be afraid to go beyond this list of suggested objects.

GOOD OBSERVING!!!

4. View the Moon through your telescope. The best time is near its crescent or quarter phases. During the Full Moon, the lack of shadows makes seeing craters difficult.

Make some sketches in the space below of what you can see. Indicate if you are seeing craters and/or mountains. Record the date, the time, the weather conditions, the part of the Moon you are observing, and any other observation you make.



OBJECT _____

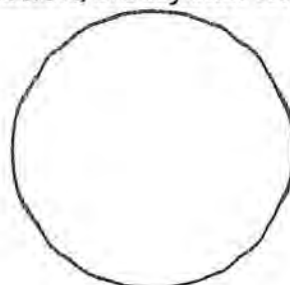
DATE _____ TIME _____

WEATHER CONDITIONS _____

COMMENTS:

5. If Jupiter is currently visible in your night sky, try to observe it. (Any almanac should provide information about its visibility and location.)

Make some sketches in the space below of what you can see. Record the date, the time, weather conditions, and any other observation you make.



OBJECT _____

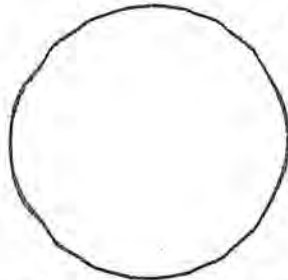
DATE _____ TIME _____

WEATHER CONDITIONS _____

COMMENTS:

6. The Pleiades is a cluster of stars found in the "shoulder" of the constellation of Taurus, the bull. On a clear night, it is easily visible to the naked eye. When it is visible at a convenient time, locate and observe it with your telescope. (The Pleiades is visible in the evening sky during the winter and early spring...in the northern hemisphere, that is...)

Make some sketches in the space below of what you can see. Record the date, the time, weather conditions, and any other observation you make.



OBJECT _____

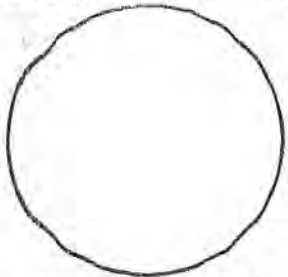
DATE _____ TIME _____

WEATHER CONDITIONS _____

COMMENTS:

7. The second star from the end of the handle of the Big Dipper (in Ursa Major, the big bear) is really two stars that appear close together. The brighter star is Mizar and the other is Alcor.

Make some sketches in the space below of what you can see. Record the date, the time, weather conditions, and any other observation you make.



OBJECT _____

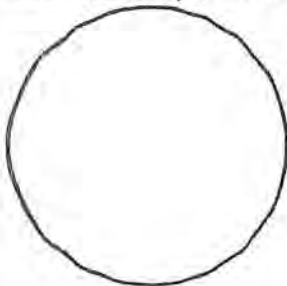
DATE _____ TIME _____

WEATHER CONDITIONS _____

COMMENTS:

8. Find the winter constellation of Orion, the hunter. If you are not familiar with the appearance of this constellation, refer to a Celestial Sphere, or to a constellation chart. The three stars in the center of the rectangle of stars are called the "belt stars." Below the belt is a bright fuzzy area called the Great Nebula. This appears as the "tip of the sword" hanging from the hunter's "belt." Locate and observe Orion and the "tip of the sword."

Make some sketches in the space below of what you can see. Record the date, the time, weather conditions, and any other observation you make.



OBJECT _____

DATE _____ TIME _____

WEATHER CONDITIONS _____

COMMENTS:

THE SPECTROMETER - MEASURING THE UNIVERSE WITH COLOR Activity 2

Isaac Newton discovered that when sunlight passed through a piece of glass with non-parallel sides (a prism) the colors of the rainbow (a spectrum) came out the other side. When a prism, used in a device called a spectrometer, is connected to the end of telescope, the spectrum of a star can be studied. The following is just a partial list of physical properties learned about analyzing the spectra of planets, stars, or galaxies: chemical composition, speed toward or away from Earth, rotation speed, temperature, density and turbulence of an atmosphere.

Another device for separating the light from a source into its spectrum is a diffraction grating. The grating consists of a transparent material onto which hundreds of lines per centimeter have been etched. As the light passes through these lines, different wavelengths of light (different colors) are bent at different angles. Many modern spectrometers make use of gratings instead of prisms. The purpose of this activity is to use a diffraction grating spectrometer to identify various light sources by observing their spectra and recognizing the chemical composition of the Sun.

FUNCTION OF THE DIFFRACTION GRATING

A diffraction grating is a device that takes light from a source and allows an observer to see what colors are mixed together to produce the color seen by the eye. Your diffraction grating is a hologram that produces a very bright spectrum of a source.

1. From the spectrometer kit, take out the plastic disk to which is glued the diffraction grating. Hold it next to your open eye (close the other eye). You will see streaks of color coming from every light and brightly illuminated object in the room. Rotate the disk. As the disk rotates, you should see the streaks of color rotate.
2. Look at an ordinary light bulb (incandescent light) through the grating disk. Rotate the disk such that the spectrum of the light is going to your left and right (not vertical).
 - a) Describe and/or draw what you see.
(Do you see colors? What color is closest to the bulb? Are there colors on both sides of the bulb?)
3. Look at a fluorescent light.
 - a) Describe and/or draw what you see.

What you **SHOULD** have seen...

The light bulb should produce a continuous line of color from red-orange-yellow-green-blue-violet coming out from the bulb with violet being the color closest to the bulb. This is the **SPECTRUM** of the light. The width of the line of color should appear as wide as the source of light. This is a **CONTINUOUS** spectrum blending from Red, Orange, Yellow, Green, Blue, to Violet (**ROYGBV**). Any heated solid will produce this kind of spectrum.

The fluorescent bulb will also produce a spectrum, as wide as the fluorescent bulb, **BUT** you should also see images of the lamp in the yellow, green and violet parts of the spectrum. The continuous spectrum is caused by the fluorescent salt coating on the inside of the tube. The bright images of the lamp are specific colors produced by the gas inside the tube. (The gas is Mercury vapor.)

The spectrometer allows you to view a light source through a thin slit. Instead of a spectrum that is the image of an extended source spread over all the colors, you will see an image of the slit spread over the colors. The spectrometer also has a scale so that specific numbers for wavelength or photon energy can be assigned to specific colors.

USING THE SPECTROMETER

Build the spectrometer using the directions in Note 2.

MATERIALS

- 1 spectrometer
- 1 incandescent light bulb (bulb with a glowing filament)
- 1 mercury fluorescent light
- colored pencils or pens
- white surface, such as a movie screen or wall

PROCEDURE

1. Turn on an incandescent light bulb, keep the room lights on, and look at the bulb through the spectrometer. Be careful to aim the slit (on the right side of the spectrometer) at the light bulb and look straight ahead at the spectrum on the scale. You should see a continuous spectrum of colors from red through violet. Mark on the scale below, Figure 1, the colors you see where you see them. Use colored pencils to shade in the observed colors.

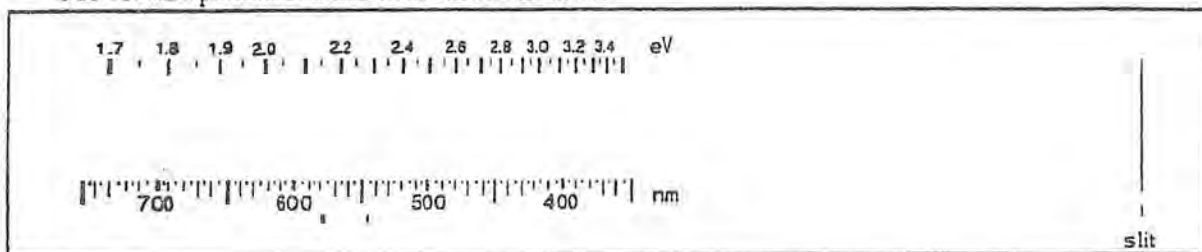


Figure 1

2. Read the number on the scale corresponding to the light farthest to the right that you can see and the number corresponding to the light farthest to the left that you can see.
 - a) The observed spectrum extends from _____ nm to _____ nm.
 - b) The colors at these places on the scale are: _____ and _____.
3. Now look at a fluorescent light through the spectrometer.
 - a) Describe the spectrum you see. Is it different from the spectrum that you observed in Step 1?
4. Again record the ends of the spectrum.
 - a) The colored spectrum extends from _____ nm to _____ nm.

The spectrum from the fluorescent light should include several bright vertical "lines". These are images of the slit. Indicate the positions of these lines on the scale below, Figure 2.

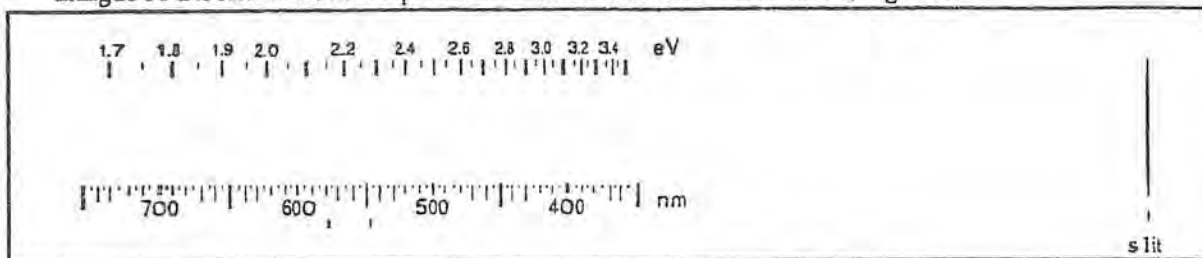


Figure 2

5. Read the positions of the bright lines on the scale and record them in Table 1.

Color	Position (nm)

Table 1

6. The most common type of fluorescent light will have the mercury emission lines superimposed on a continuous spectrum. The green line of mercury occurs at 546 nm. If your value in Table 1 does not agree with this standard value, adjust the position of the scale in your spectrometer.

Color	Position (nm)

Table 2

7. Point the slit of your spectrometer at a white surface that has fluorescent light shining on it, such as a wall or a movie screen, and measure the ends of the spectrum and the positions of any bright lines that you see. Record your data in Table 2.

a) Compare the results of Steps 5 and 6. Was the spectrum that you saw from the fluorescent light similar to or different from the spectrum you saw when you looked at the white surface?

b) Why do you think the spectra were similar or different?

8. Use your spectrometer to observe as many other light sources as you can find. Suggested lights include the red or green LEDs (Light Emitting Diodes) on a VCR (Video Cassette Recorder) or stereo system; chemical light sticks; and ordinary light bulbs observed through transparent, colored objects.

List the object and describe the spectrum you observed.

(Are there any bright or dark lines in the spectrum? If there are any bright or dark lines, give the positions and the colors of the lines.)

Object 1: _____

Description of spectrum: _____

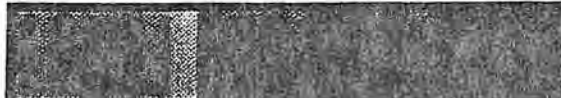
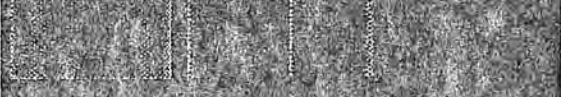
Object 2: _____

Description of spectrum: _____

Object 3: _____

Description of spectrum: _____

9. You will now identify the spectrum of some unknown lights. Observe the spectra of some indoor lights and a few street lights or security lights. Write the letter of the observed spectrum (on the left) on the blank that corresponds with the type of light (and its apparent color) on the right.

SPECTRA OF SELECTED LIGHTS					TYPE OF LIGHT (appearance to naked-eye)		
	red	orange	yellow	green	blue	violet	
A.							_____ incandescent light bulb (yellow white)
B.							_____ high pressure sodium (orangish yellow)
C.							_____ fluorescent light (bluish white)
D.							_____ low pressure sodium (yellow)
E.							_____ mercury vapor (blue)

10. Take your spectrometer outside (or look through a window from a darkened room) and point the slit toward the bright sky near the Sun.

DO NOT LOOK DIRECTLY AT THE SUN!! IT CAN DAMAGE YOUR EYES!!

You should see a spectrum of all the colors with narrow, dark lines superimposed. Measure the ends of the spectrum.

- a) The spectrum extends from _____ nm to _____ nm.

Now measure the positions of the dark lines that you see. Record the results in Table 3.

Missing Color	Position (nm)

Table 3

11. Compare the absorption lines you observed in the Sun's spectrum with those listed in Table 4.
 - a) What elements do you conclude are present in the Sun?
 - b) Do you think that you have found all the elements that are in the Sun? Why or why not?
 - c) Where do you expect that elements would have to be located in order to cause dark absorption lines in the spectrum of the Sun? (Would they have to be located inside the Sun, on the Sun's surface, above the Sun's surface, in space between the Sun and the Earth, or in the Earth's atmosphere?)
12. Point the spectrometer slit at a bright, white cloud.
 - a) Describe the spectrum that you see. How does the "cloud" spectrum compare to the spectrum of the Sun? Does the cloud spectrum have dark lines as the solar spectrum does?
 - b) Why do you think the cloud spectrum appears the way it does?
13. Look at the Moon through the spectroscope. (This activity is best done at night when the Moon is bright compared to the background sky, such as when there is a full Moon visible two or three hours after sunset.)
 - a) Describe the spectrum. (How does the Moon's spectrum compare to the spectrum of the Sun? Does the lunar spectrum have dark lines as the solar spectrum does? Are they the same lines? Why or why not?)

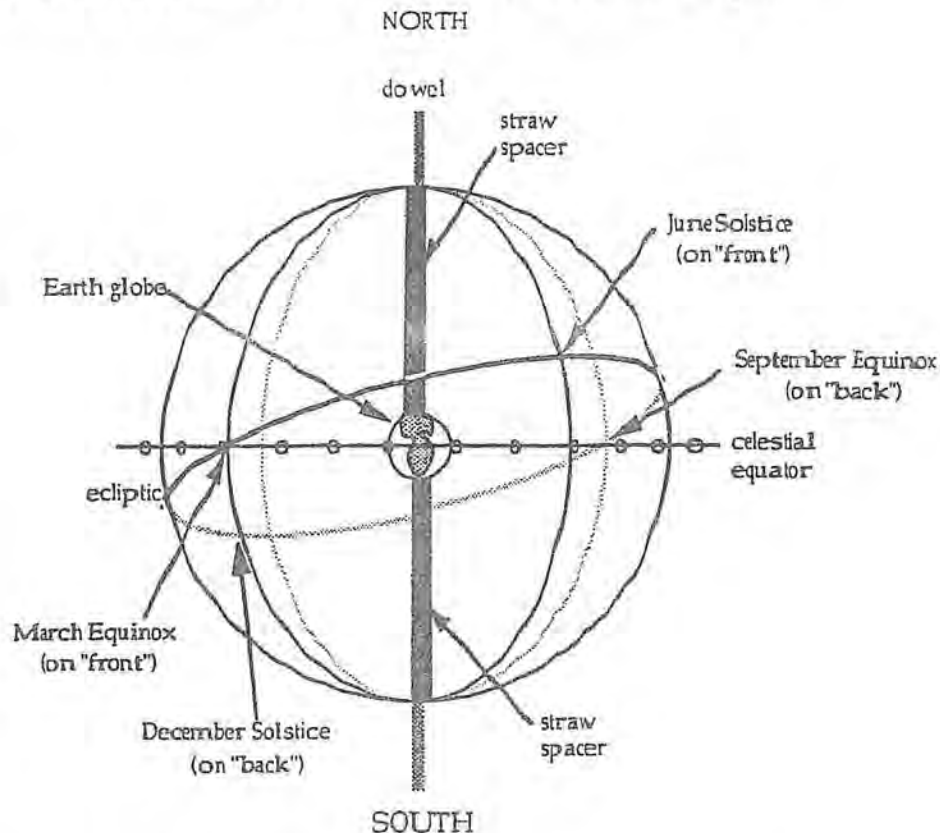
Table 4

ABSORPTION LINES IN THE SUN
(from the *CRC Handbook of Chemistry and Physics*)

Line	Due to	Wavelength (nm)	Line	Due to	Wavelength (nm)
M	Iron	372.8	b ₄	Iron	516.8
L	Iron	382.0		Magnesium	516.7
K	Calcium	393.4	b ₂	Magnesium	517.3
H	Calcium	396.8	b ₁	Magnesium	518.4
h	Hydrogen	410.2	E ₂	Iron	527.0
g	Calcium	422.7	D ₂	Sodium	589.0
G	Iron	430.8	D ₁	Sodium	590.0
G'	Calcium		C	Hydrogen	656.3
G'	Hydrogen	434.0	B	Oxygen	759.4
F	Hydrogen	486.1		Oxygen	762.1

THE CELESTIAL SPHERE - MODELING THE SKYActivity 3

For thousands of years, people have made models of the sky to help them know when to plant and harvest crops and when to celebrate religious holidays. One classic model of the sky is the celestial sphere. The Earth is located at the center of the sphere with the stars, Sun, Moon, and planets on the inside surface of the sphere. By setting the Sun for a specific date and the horizon for a given latitude, one can reproduce the daily motion of the Sun and stars in the sky for that day. In this activity you will use a celestial sphere to investigate the daily and annual motions of the sun and stars as seen from different latitudes for each season of the year.



Your celestial sphere should appear as shown in the diagram above. You will use this to predict the daily motion of the sky for the beginning of each season. The ECLIPTIC is the apparent path of the Sun on the celestial sphere for the entire year - as the Earth moves around its orbit, the Sun appears to move against the background stars. Each point on the ecliptic represents the position of the Sun for a given day of the year. The four dates specifically indicated represent the beginning of each season. The March Equinox (Spring or Vernal equinox) occurs on or about March 20; the June Solstice (Summer Solstice) on or about June 21; the September Equinox (Fall or Autumn Equinox) on or about September 22; and the December Solstice (Winter Solstice) on or about December 21.

MODELING THE SUN'S DAILY MOTION with the CELESTIAL SPHERE

The celestial sphere is slanted at an angle of 40° to the horizon. This means that the sphere is adjusted to model the motions of the sky for an observer at a latitude of 40° north of the equator. The observer, YOU, must imagine that you are standing on the earth globe at a latitude of 40° north. Your horizon is parallel to floor, and zenith is directly overhead. (Figure 1)

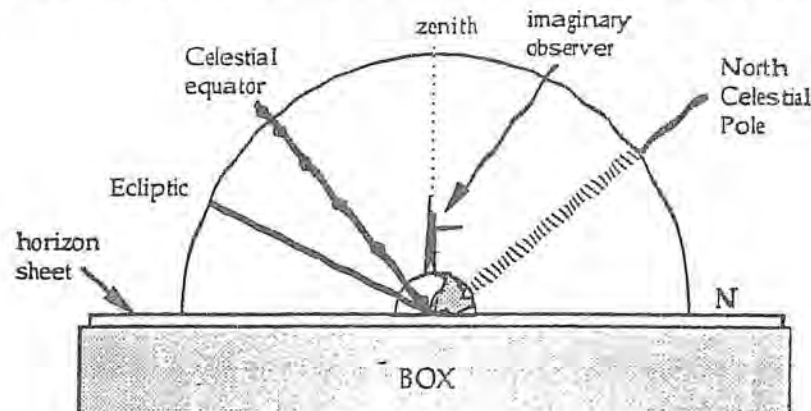


Figure 1

Answer all of the following questions as if you were a VERY small person (imaginary observer) standing on the Earth globe observing the motions of the Sun (the map pin) for the given dates. You will always be standing VERTICAL on the globe, no matter the latitude at which the celestial sphere is set. (Any numbers you are asked to determine may be slightly incorrect because of the estimation in setting the celestial sphere to the proper latitude and the dowel may slip a little in the foam base.)

1. With the celestial sphere sitting in the horizon box, stick the map pin (the Sun) into the position on the ecliptic that matches the Sun's position for the March Equinox, around March 20. This will be on the celestial equator. Make sure that the sphere is properly aligned with north.
2. 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 next level with the top of the box, 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.

3. Repeat step 2, moving the Sun marker from sunrise to sunset. Count the bumps that pass the western horizon (or any fixed reference point). This is the approximate number of hours of daylight for March 20. (Write the answers based on what you observe not on what you think is correct.)
 - a) From what direction did the Sun rise?
 - b) In what direction did the Sun set?
 - c) About how many hours of daylight were there in that day?

4. Observe the apparent path of the Sun in the sky (for March 20) as demonstrated with the celestial sphere.
 - a) In what direction is the Sun when it is at its highest in the sky?
 - b) How many degrees is the Sun above the horizon when it is at its highest?
5. In describing the apparent position of an object in the sky one must use the directions to face (i.e., north, south west, etc.) to view the object and the approximate distance (i.e., half way, 2/3, etc.) from the horizon to the zenith. Keep this in mind when answering the following questions.

Set the celestial sphere for three hours after sunset, about 9 pm local standard time for March 20.

- a) Describe the position of the BIG DIPPER in the sky.
- b) Describe the position of ORION, the hunter, in the sky.
- c) Describe the position of LEO, the lion, in the sky.
- d) Describe the position of CYGNUS, the swan (northern cross), in the sky.

Compare your observations of the Sun and constellations with the following information for an observer at 40° north latitude on March 20:

- a. The Sun rises from the east and sets in the west and is in the sky for about 12 hours.
 - b. The Sun is highest in the sky at noon (by a sundial) and is 50° above the Southern horizon.
 - c. At 9 pm (standard time) the BIG DIPPER will be about 2/3 of the way from the northeastern horizon towards zenith, ORION will be about 1/3 of the way above the southwestern horizon, LEO will be about 2/3 of the way up in the southeast and CYGNUS should be below the northeastern horizon.
6. Repeat the same observations for the Summer (or June) Solstice, which occurs around June 21. Move the Sun to that position on the ecliptic (north of the celestial equator) and rotate the sphere as in steps 3 -5.
 - a) From what direction did the Sun rise?
 - b) In what direction did the Sun set?
 - c) About how many hours of daylight were there in that day?
 - d) In what direction is the Sun when it is at its highest in the sky?
 - e) How many degrees is the Sun above the horizon when it is at its highest?
 - f) How does this compare to the same observations from March 20?
- For 9 pm standard time,
- g) Describe the position of the BIG DIPPER in the sky.
 - h) Describe the position of ORION, the hunter, in the sky.
 - i) Describe the position of LEO, the lion, in the sky.
 - j) Describe the position of CYGNUS, the swan (northern cross), in the sky.
 - k) How does this compare to the same observations from March 20?

8. Repeat the same observations for the September (or Autumnal) Equinox, which occurs around September 22 and the December (or Winter Solstice), around December 21. Move the Sun to these positions. Repeat steps 3 - 5, answering the same questions. Complete the following charts.

Daily motion of the Sun as seen from a latitude of 40° north for the beginning of each season:

DATE	Sunrise direction	Altitude of SUN at local noon	Sunset direction	Hours of day light
March 20				
June 21				
September 22				
December 21				

Positions of selected constellations at 9 p.m. standard time for the beginning of each season:

DATE	BIG DIPPER	ORION	LEO	CYGNUS
March 20				
June 21				
September 22				
December 21				

9. Repeat the same observations for March 20, except this time set the Celestial Sphere for an observer at the Equator. Take the sphere out of the foam base and lay it across the cut out of the box with the north pole and south pole of the dowel on the North and South positions on the box, respectively. (Figure 11)

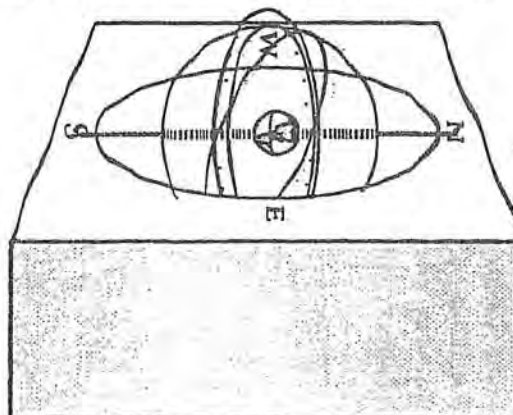


Figure 11

- a) From what direction did the Sun rise?
b) In what direction did the Sun set?

- c) About how many hours of daylight were there in that day?
- d) In what direction is the Sun when it is at its highest in the sky?
- e) How many degrees is the Sun above the horizon when it is at its highest?
- f) How do these observations compare with those for March 20 at 40° north latitude?

For 9 p.m. standard time,

- g) Describe the position of the BIG DIPPER in the sky.
- h) Describe the position of ORION, the hunter, in the sky.
- i) Describe the position of LEO, the lion, in the sky.
- j) Describe the position of CYGNUS, the swan (northern cross) in the sky.
- k) How do these observations compare with those for March 20 at 40° north latitude?

10. Repeat the same observations for the remainder of the year (June 21, September 22, and December 21) and complete the following tables.

Daily motion of the Sun:

DATE	Sunrise direction	Altitude of SUN at local noon	Sunset direction	Hours of daylight
March 20				
June 21				
September 22				
December 21				

Positions of stars in the sky at 9 p.m. local time (direction to face and altitude above horizon):

DATE	BIG DIPPER	ORION	LEO	CYGNUS
March 20				
June 21				
September 22				
December 21				

11. Now set the celestial sphere for an observer at the North Pole. Place the celestial sphere at an angle of 90° from the horizontal (vertical) into the foam base. Adjust the position of the sphere such that the horizon sheet is the same height as the center of the Earth globe. (Figure 13)

Position the Sun for March 20. Turn the celestial sphere so the Sun is in the south (at noon).

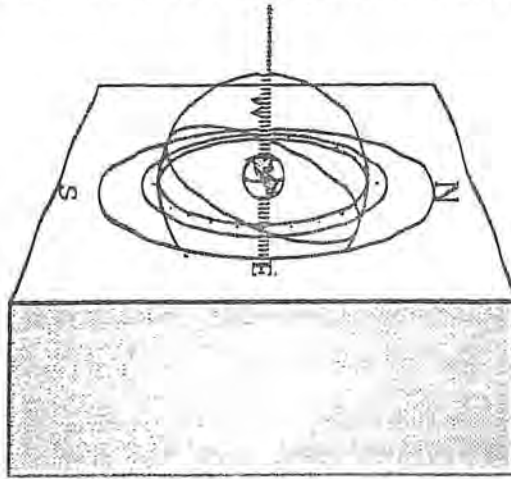


Figure 12

- a) How many degrees is the Sun above the horizon?

Rotate the sphere until the sun sets.

- b) In what direction does the Sun set?

- c) Describe what the Sun appears to do in the sky at the North Pole on the March 20:

Position the Sun for June 21.

- d) Describe the motion of the Sun in the sky at the North Pole for June 21:

Position the Sun for September 22.

- e) Describe the motion of the Sun in the sky at the North Pole for September 22:

Position the Sun for December 21.

- f) Describe the motion of the Sun in the sky at the North Pole for December 21:

When the sky is dark at the North Pole, describe the position of the following stars and constellations in the sky:

- g) BIG DIPPER

- h) CYGNUS

- i) LEO

- j) ORION

- k) Describe the motions of these stars during one 24-hour interval.

- l) When would these stars be visible in the sky?

NOTE: Use the lenses separately for the first part of the telescope activity and then complete its construction.

1

BUILDING AN ASTRONOMICAL TELESCOPE

MATERIALS (included in kit)

- 2 cardboard tubes (one slightly smaller than the other)
- 1 foam lens holder
- 1 1/2 inch spacer
- 1 plastic cap
- 1 cardboard washer
- 1 large lens
- 1 small lens

(NOTE: To avoid scratching the lenses, place them on a piece of paper or cloth.)

PROCEDURE

Refer to Figure 1 for the following instructions.

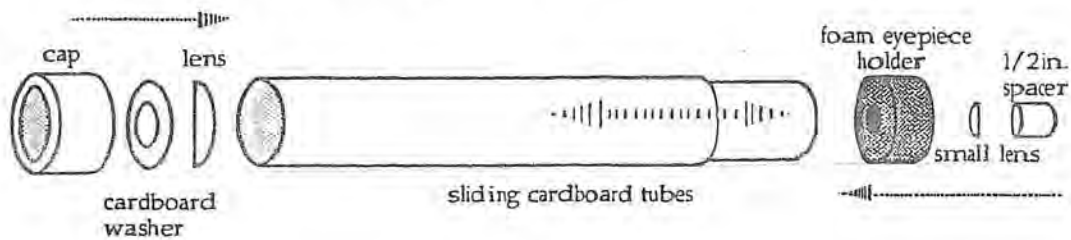


Figure 1

1. Pick up the large lens, being careful not to smudge it with your fingers. Fit the curved side of the lens snugly against the front of the outer tube, making sure it is positioned perpendicular to and centered on the tube. Slip the plastic cap over this end of the tube so that the lens is firmly held in place.
2. Using the small piece of cloth or tissue to prevent smudging, push the small lens into the foam lens holder.
3. Slide the spacer into the foam holder such that it pushes against the flat part of the lens. Push the spacer into the holder just far enough so the end of the spacer is flat with the end of the foam holder.
4. With the curved side of the lens facing toward the large lens, slide the foam holder into the end of the smaller of the sliding tubes. The foam holder should be flat with the end of the tube.

NOTE: Use the diffraction grating disk for the first part of the spectrometer activity and then complete its construction.

2

BUILDING A SPECTROMETER

Materials (included in kit)

- | | |
|---------------------------------------|---|
| 2 cardboard sections (top and bottom) | 1 film strip scale |
| 2 foam side pieces | 1 plastic disk with diffraction grating |
| 5 pairs of nuts and screws | 1 support tube (3/4") |

Procedure

1. Lay one of the spectrometer body sections on a level table with the narrow end towards you and the pointer on your right. (Figure 1)
2. Lay the longer foam side piece on the left hand side of the body section such that the two screw holes are covered and the outside edge of the foam is even with the outside edge of the body section. Position the shorter foam piece in a similar fashion on the right hand side of the body section. All four holes should be covered by the foam pieces. Stand the diffraction grating disk in the wide slit at the narrow end of the body section. Stand the support tube (3/4") centered over the screw hole in the middle of the cardboard section. (Figure 2)

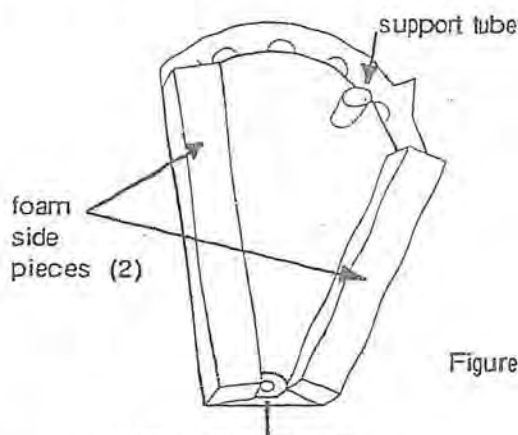
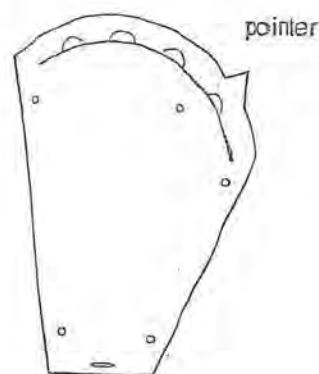


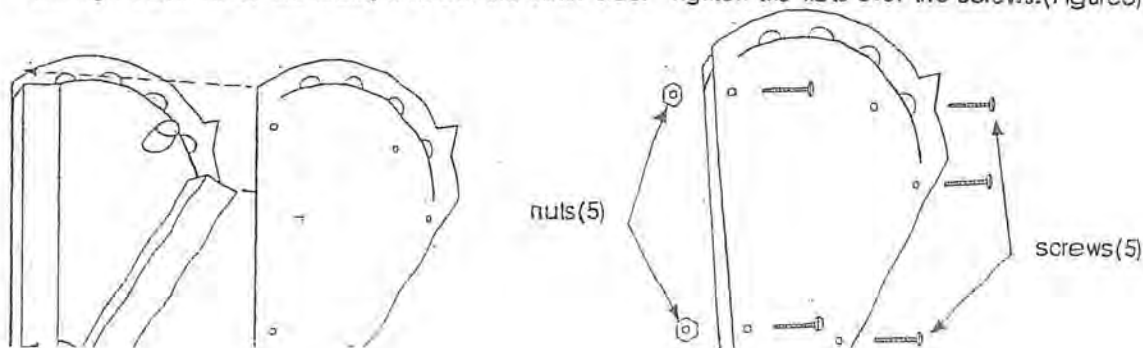
Figure 2

Figure 1



(note the side with the plastic film should face into the spectrometer not toward your eye)

3. Position the other body section over the arrangement on the table. Lay it on the foam pieces such that the top of the grating disk fits into the wide slit on the narrow end of the upper body section. Make sure that the body sections are parallel to each other. This means that the pointer must be on the RIGHT hand side!!! Fit the screw through the support tube as illustrated and put the nut on it. There are no holes in the foam. Therefore, you must push the screws through each hole, the foam, and out the other side. Tighten the nuts over the screws. (Figure 3)



4. Hold the spectrometer body with the pointer to the right. Slide the film strip into the curved slot on the wide end of the spectrometer. Keep the vertical slit on the film strip to the right. The transparency should be positioned so that the sprocket hole of the film just protrudes beyond the top and bottom of the spectrometer body. Apply the label to the TOP of the spectrometer. Follow the instructions in the activity and on the label to adjust the film strip for the proper colors. (Figure 4)

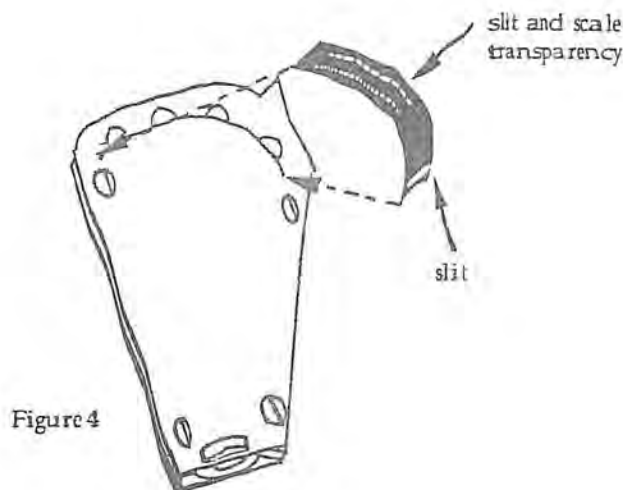
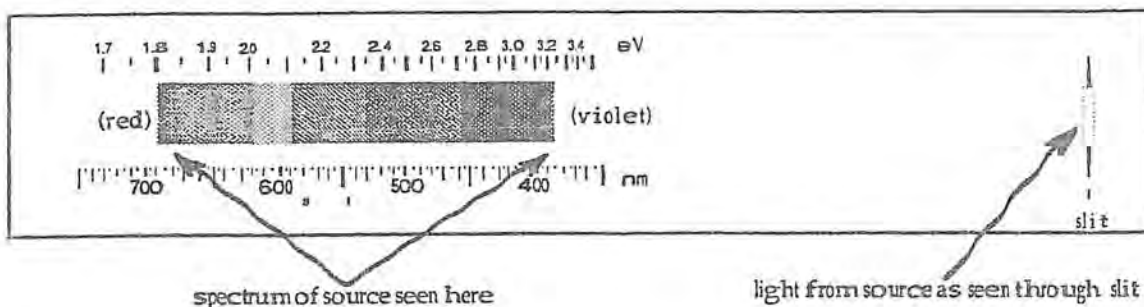


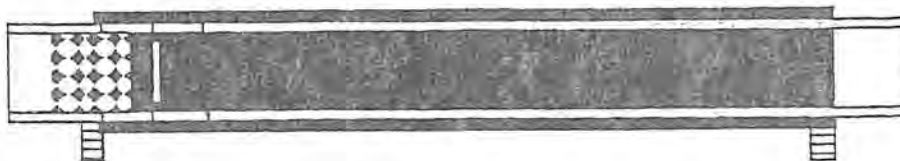
Figure 4

5. When held to the eye and viewed through the small circular opening on the grating disk, you should see the scales reading from left to right and the vertical slit on the right. To view the spectrum of a light source, put your eye to the grating and aim the pointer at the source. Adjust the position of the spectrometer until the vertical slit is illuminated by the light source. (Figure 5)



6. Rotate the grating disk so that the spectrum of the source is horizontal to the left of the slit between the two scales. (Figure 5)

Note to Spectrometer Users: Please use the Black Tape that is Securing the film to the spectrometer to cover up the gap between the foam and the film. Placement of the tape is indicated by the checkered area shown below. This should stop any excess light from entering the spectrometer. Don't cover up the slit which lets the light in.





BUILDING A CELESTIAL SPHERE

MATERIALS (included in kit)

- 1 star chart sheet
- 2 plastic hemispheres
- 1 erasable marking pen
- 1 wooden dowel
- 1 small Earth globe
- 1 plastic drinking straw

- 4 adhesive disks
- 1 foam block
- 1 horizon sheet
- 1 box (in which kit was packed)
- 1 map pin
- 1 small protractor (to be cut out)

other materials (not in kit):

- 1 pair of scissors

PROCEDURE

1. Prepare the two star charts by cutting along the outside lines with the scissors. The star chart will look like a black flower with eight petals. The white line that crosses four of the petals is the **ECLIPTIC**. This line represents the apparent path of the Sun against the stars due to the motion of the Earth along its orbit around the Sun. The constellations found along the ecliptic are the signs of the Zodiac.

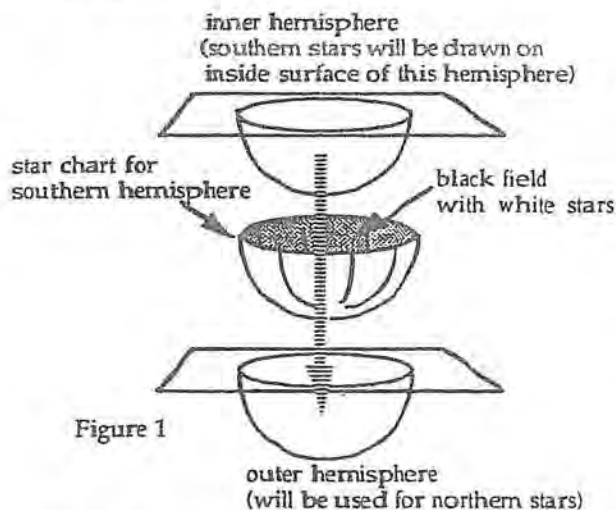


Figure 1

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 four 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. Make sure that the ridges of both hemispheres match. Tape the edges of the two hemispheres together. (Figure 1)

3. Mark the stars on the inside of the inner hemisphere with the erasable marking pen. Also, draw the lines that mark the ecliptic and some brighter constellations. The brighter stars are indicated by bigger symbols. (The "magnitude" of a star is an indication of its apparent brightness. On this chart, a zero magnitude star is the brightest and the fourth magnitude star is the dimmest. The unaided human eye can see stars as dim as +6.5 magnitude.) (Figure 2)

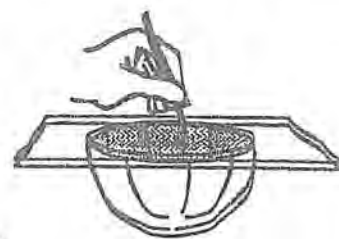
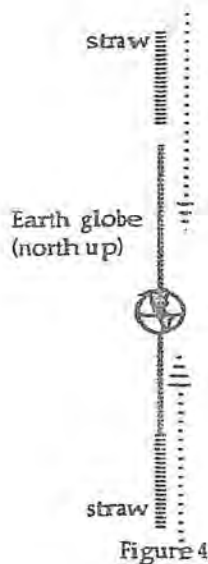
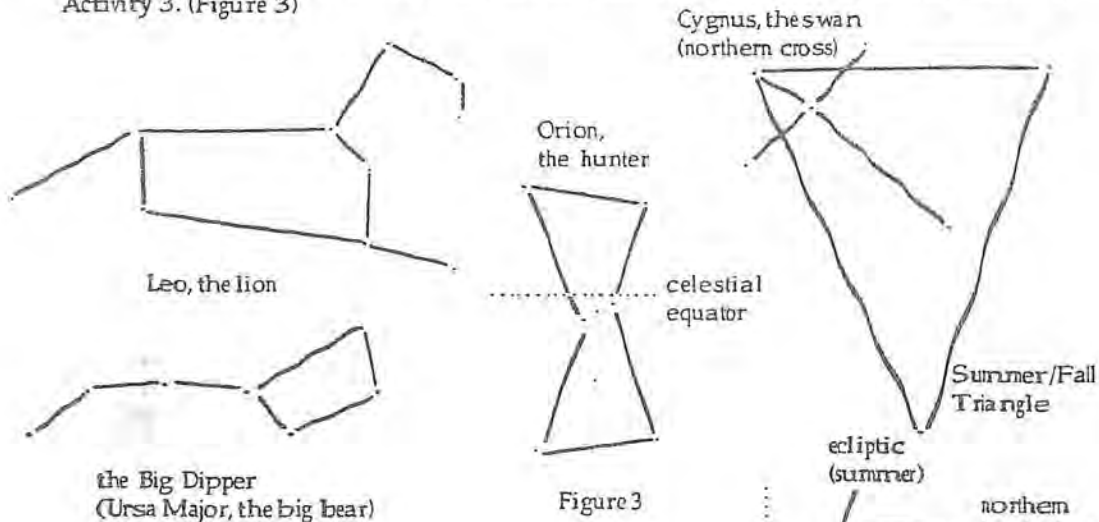


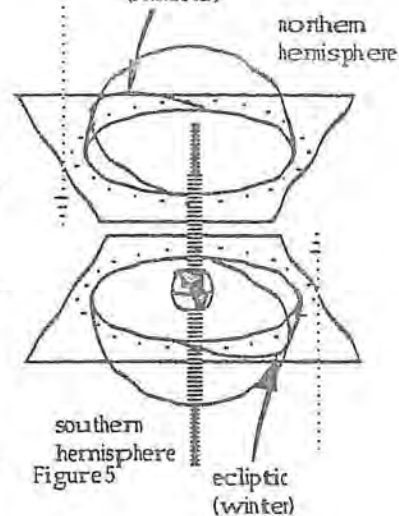
Figure 2

4. When you have marked all the stars, separate the hemispheres and remove the star chart. Repeat steps 2 and 3 with the northern star chart and the other, unmarked hemisphere (the "outer" hemisphere in Figure 1). Confirm that the ecliptic lines touch the base at opposite ridges. (Use the hemisphere you have already marked to secure the chart in place.)

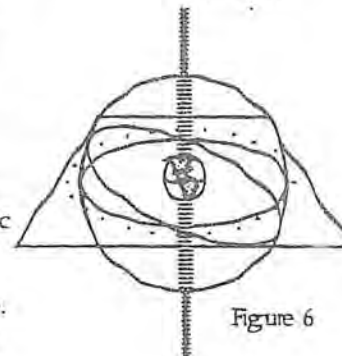
5. Look into the northern hemisphere. Stars in some of the constellations are connected with lines. Pay particular attention to four of them: LEO, CYGNUS with the Summer/Fall Triangle, and the BIG DIPPER (an easily recognized pattern, not a true constellation), and the northern half of ORION (the bottom of ORION is in the southern hemisphere). You will be referring to them in Activity 3. (Figure 3)



6. 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)
7. Place four of the adhesive disks on the bottom of ONE hemisphere under the dimple at each ridge. (Figure 4)
8. 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)



9. 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. Evenly space the four adhesive disks around the base of one hemisphere under a dimple. Press the hemisphere together, sticking with the adhesive disks. (Figure 6)



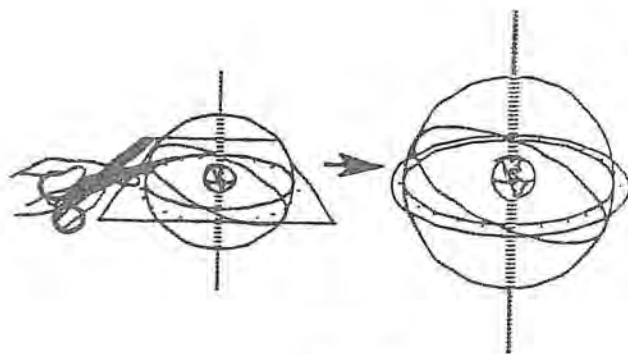


Figure 7

10. Turn the rim of the plastic sphere leaving the dimples. The clear plastic sphere should rotate freely on the dowel. The entire celestial sphere assembly (hemispheres and globe) should slide tightly up and down the dowel. (Figure 7)

11. Cut out the small Latitude Protractor on the last page. Match the dowel with the line for 40° marked on the protractor. Push the dowel into the foam block at this angle. Be careful to place the sphere in the block such that the center of mass of the sphere is over the block. This should insure that the sphere will stand freely on the block. (Figure 8)

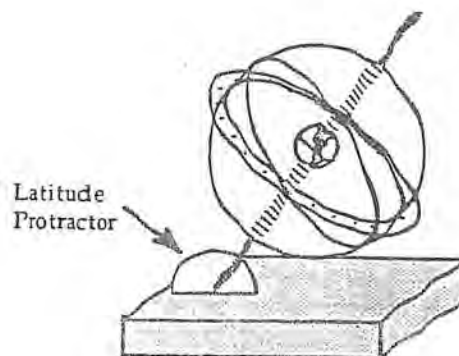


Figure 8

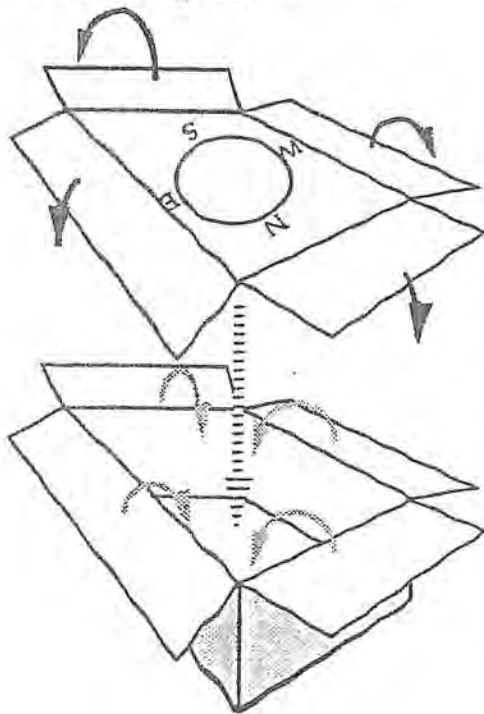


Figure 9

12. Fold the lapels of the box in which the kit arrived into the box, pushing them as tightly to the sides of the box as possible. Cut out the circle on the horizon sheet. Fold the edges of the horizon sheet down and place the sheet in the box. The top of the sheet labeled with the directions, N, S, E, and W, should form a horizontal surface even with the top of the box. (Figure 9)

13. Set the celestial sphere in the box through the hole in the horizon sheet. Adjust the position of the sphere on the dowel until the center of the Earth globe is level with the horizon sheet. Align North on the celestial sphere with North on the horizon sheet. (Figure 10)

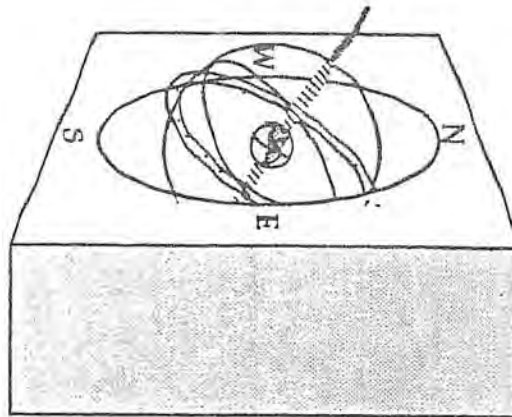
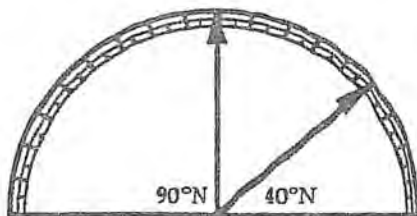


Figure 10



Latitude Protractor