Teacher's Guide of Short Programs for

MEDIAGLOBE DIGITAL PLANETARIUM

3
Reasons For The Seasons

Written by Art Klinger
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Ver.1.0

KONICA MINOLTA PLANETARIUM CO., LTD.

The essentials of imaging
INTRODUCTION

First of all don't panic at the size of this booklet! You are not expected to cover ALL of the following material. However, we would like you to pick and choose the activities from each Lesson that you think will cover the Big Ideas and the Leading Questions. The Unit Concepts are classified as follows:

Earth Motions and Shapes; Circumpolar Star Finder; Reasons for the Seasons

To complete the Unit Concepts it would be helpful if you and your class visit a Media Globe/Planetarium Facility at least twice during the school year.

PHILOSOPHY

The philosophy for this booklet is: sequential learning by practical application. Hopefully, learning will occur by the repeated use of terms and concepts handed down from one activity to another. This along with hands-on practical application activities will produce the outcomes vital to the learning process.

Astronomy is not just looking at the stars. Astronomy spans many subjects like: Geography, History, Geometry, Trigonometry, Biology, Chemistry, Physics, Philosophy, Religion and the pseudo science of astrology. This sequential course of astronomy will cover or touch upon all of those subjects.

Finally, a Media Globe/Planetarium facility gives you the opportunity to explore every ancient point of light that our ancestors recognized as stars and planets. By studying other worlds, we will better understand our own.

GENERAL OBJECTIVE

We believe the Media Globe/Planetarium Facility should be a place where learning can be exciting. Here, the students will be able to apply or see the application of the lessons they learned in this booklet.

WEB LINKS

Abrams Planetarium: www.pumsu.edu/abrams/diary.html
Jet Propulsion Laboratory: www.jpl.nasa.gov
NASA Education: www.education.nasa.gov
Paper Plate Astronomy: http://analyzer.depaul.edu/paperplate
Transit of Venus: http://analyzer.depaul.edu/paperplate/transit.htm
**Reasons for the Seasons**

UNIT CONCEPTS: Earth & Sky Motions, Reasons for Seasons

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<th>GUIDING QUESTIONS</th>
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<td>A. The Sun appears to move from east to west because the Earth rotates from west to east</td>
<td>1. What direction does the sun come up and go down?</td>
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<td>B. The sun is a star. All stars except one appear to move from east to west. The exception is the North Star (Polaris).</td>
<td>2. Does the Sun really come up and go down?</td>
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<td>C. Stars appear to move because the Earth is turning. However, there are two places on the Earth that do not move; they are the North Pole and the South Pole.</td>
<td>3. Why does the Sun appear to come up and go down?</td>
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<td>D. Anything located above the North Pole and/or South Pole will not appear to move since both locations are not turning. That is why the North Star, called Polaris, or Pole Star, doesn’t move.</td>
<td>4. Point to the direction the Earth turns.</td>
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<tr>
<td>E. At our latitude (40°N) we are moving nearly 800 mph even though it feels like we’re not moving at all.</td>
<td>5. Name a star that doesn’t even appear to move.</td>
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<td>F. The shadow of a gnomon moves clockwise from west to east with the shortest shadow occurring at noon.</td>
<td>6. Name two locations on the Earth that don’t move as the Earth turns?</td>
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<td>G. Latitude and Longitude what it means and how it is measured.</td>
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<td>H. Establishment of Equator, Tropics of Cancer and Capricorn, Arctic and Antarctic Circles and Land of Midnight Sun</td>
<td>8. At our latitude we’re moving nearly 800 mph, why can’t we feel it?</td>
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<td>I. Proof: Earth is Round, Rotates, Revolves and Precesses</td>
<td>9. Why do the hands of a clock go clockwise instead of counterclockwise?</td>
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<td>J. Astrology is a Pseudo-Science</td>
<td>10. What two directions can be determined at noon?</td>
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<p>| K. From a vantage point out in space we can see that during the summer the North Pole is tilted toward the Sun and is tilted away during the winter. This makes the summer noon sun high in the sky and the winter noon sun is at its lowest. | 1. Why is the noon Sun high in the summer and low in the winter? |
| | 2. Why are daylight hours longer in the summer than in the winter? |
| | 3. Why is it hot in the summer and cold in the winter? |</p>
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<th>From our Earth view we can see that</th>
<th>1. What geographical location is associated with the path of the Sun on June 21?</th>
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<td>L. Summer begins when the noon Sun is at its highest point for the entire year</td>
<td>2. Why is the first day of summer called the longest day of the year?</td>
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<td>M. Fall and spring begin when the Sun comes up directly from the east and sets directly west.</td>
<td>3. What geographical location is associated with the path of the Sun on Sept. 23 and Mar. 21?</td>
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<td>N. Winter begins when the noon Sun is at its lowest noon position for the entire year.</td>
<td>4. What geographical location is associated with the path of the Sun on December 21?</td>
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<td>O. We have seasons because the Earth is tilted and it goes around the Sun</td>
<td>5. Why is the first day of winter called the longest night of the year?</td>
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<td>P. Summer is hotter than winter because the Sun angle is higher and the Sun stays up longer in Summer; thus longer daylight hours.</td>
<td>6. Why do we have seasons?</td>
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<tr>
<th>Q. <strong>Circumpolar constellations</strong> here at our latitude are represented by 5 constellations in the northern sky that go counterclockwise around Polaris. These constellations never ever go below the horizon.</th>
<th>1. What is a circumpolar constellation and how many can be viewed at our latitude?</th>
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<td>R. Circumpolar Constellations move counterclockwise around Polaris 15 degrees per hour.</td>
<td>2. Why do the circumpolar constellations appear to move each hour?</td>
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<td>3. Where is the Big Dipper at 8pm on the first day of Summer, Fall, Winter and Spring?</td>
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<td>4. What is a drinking gourd? Where is it in the sky? Why did the slaves follow it?</td>
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# Reasons for Seasons

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(S-Science, G-Geography)  
SS-Social Studies, H-History, M-Math

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# LESSON 1: Earth Motions & Shape

## Vocabulary

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<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>Astrology</td>
<td>A false science based on the positions of stars and planets</td>
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<tr>
<td>Circumference</td>
<td>Distance around an object</td>
</tr>
<tr>
<td>Constellation</td>
<td>Shapes or patterns that stars seem to make</td>
</tr>
<tr>
<td>Ecliptic</td>
<td>The imaginary plane the Earth orbits as it goes around the sun. The imaginary line that connects the Earth and all the planets to the Sun</td>
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<tr>
<td>Eratosthenes</td>
<td>A man (200 B.C.) who determined the circumference of the Earth using a stick and common sense. His method of measurement proved the Earth was round</td>
</tr>
<tr>
<td>Latitude</td>
<td>Lines parallel to the equator measured in degrees north and south of the equator</td>
</tr>
<tr>
<td>Longitude</td>
<td>Lines (also called meridians) running from pole to pole measuring degrees east and west of Greenwich England (the prime meridian)</td>
</tr>
<tr>
<td>Parallax</td>
<td>The apparent back and forth shift of a distance object as viewed from two different locations</td>
</tr>
<tr>
<td>Pendulum</td>
<td>A device that hangs from a ceiling that swings freely back and forth</td>
</tr>
<tr>
<td>Planet</td>
<td>An object that directly orbits a Star. It reflects the light of its nearby star.</td>
</tr>
<tr>
<td>Polaris</td>
<td>Called the North Star it is a star located directly above the Earth's North Pole. Since the North Pole doesn't move neither does the North Star; thus, always showing us the direction of North.</td>
</tr>
<tr>
<td>Precession</td>
<td>The wobbling of the Earth's axis. One wobble takes 25,800 years</td>
</tr>
<tr>
<td>Revolution</td>
<td>Orbiting around another object</td>
</tr>
<tr>
<td>Rotation</td>
<td>Turning on one's axis</td>
</tr>
<tr>
<td>Star</td>
<td>A hot ball of gas that gives off its own light and heat.</td>
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<td>Zodiac</td>
<td>Constellations located along the ecliptic</td>
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LESSON 1: Earth Motions & Shape

ACTIVITY 1 Does the Sun Move?

Objective

The stars (including our Sun) appear to rise from the east and set in the west. The student will be able to explain and demonstrate why the Sun and stars appear to move from east to west.

Materials

1. Direction cards taped on the walls of your room. For this all you need are four sheets of paper, a black or blue Magic Marker. On one sheet of paper mark an "N" for north and tape it to the north wall, etc.

2. A lamp without a shade and a 60 or 75 watt light.

CLASSROOM SET UP

Set the light source near the center of your room. Your classroom should be set up as follows.

```
North

West                   East

Light Source

South
```

PROCEDURE

1. Ask them: “What direction does the Sun come up?” ANS: East

2. “Does the Sun really come up?” ANS: No

3. “Why then does the Sun appear to come up”? ANS: Earth is turning

4. “I want everyone to point in the direction (N, E, S, W) the Earth is turning.” ANS: You’ll have students every which way
5. Stand at the west wall and ask your students: What direction is the Sun (75 watt light source) from me?"  
   **ANS:** East

6. Ask them: "What direction am I from the Sun?"  
   **ANS:** West

7. Walk toward the east. Ask the students: "What direction am I moving toward?  
   **ANS:** East

8. Walk toward the east wall and stop when the Sun is directly south of you. Ask the students: "What direction is the Sun from me?"  
   **ANS:** South

9. "Did the Sun really move from east to south?"  
   **ANS:** No

10. "Why did the Sun appear to move from east to south?"  
    **ANS:** "Because I was moving"

11. "What time of day is it when the Sun is south?"  
    **ANS:** Noon, the Sun is half way between east and west.

12. Walk to the east wall and ask them: "What direction is the Sun from me right now?"  
    **ANS:** West

13. "Did the Sun really move from east to west?"  
    **ANS:** No

14. "Why did the Sun appear to move east to west for me?"  
    **ANS:** Because you were the one doing the moving.

15. Ask them to sit perfectly still and then say, "at the count of three I want everyone to point in the direction that the Earth is moving at this moment."
    **ANS:** Many students will point east; therefore, you'll probably need to do this demonstration a second or third time. It is hard to get students to understand that we are moving in a direction since we feel like we're standing still.

16. Conclusion: "Therefore, the Earth rotates from the........to the........."  
    **ANS:** west to east

17. "And everything in our southern sky moves the opposite way from........to........"  
    **ANS:** east to west
ACTIVITY 2  Why Doesn't the North Star Appear to Move?

Objective

The students should be able to explain and demonstrate that the only reason stars seem to move is because the Earth is turning. However, the North Star (Polaris—the pole star) doesn't even appear to move because it is located above the North Pole which in fact doesn't move either. Therefore, sky motion is a direction function of Earth motion. And since the axis stays in place so does the North Pole and the North Star, which is directly above the North Pole.

Materials:

1. A regular sized rotating globe.

PROCEDURE/INTERPRETATION

1. With globe in hand, walk to the center of your classroom so that all the students have an equal view of you and the globe. Rotate the globe many times and while doing so ask them: "Are there any places on the globe that are not moving?"  **ANS:** Yes, the North and South Poles which make up the axis of the Earth.

2. Ask them: "Why do the stars (Sun) appear to move in the sky?"  **ANS:** We just learned that the stars appear to move because the Earth is rotating.

3.  "We just learned that there are two places on the Earth that do not move the North and South Pole. Therefore, if the North Pole doesn't move and the North Star doesn't move the North Star must be located directly above the......"  **ANS:** North Pole

4. "Another name for the North Star is Polaris. What do you think Polaris means?"  
   **ANS:** It means the "Pole Star."
ACTIVITY 3  Why Do The Hands of a Clock Move Clockwise?

Objective

Students should be able to explain and demonstrate that the hands of a clock move clockwise which is the same as the shadow of a stick.

Materials:

1. A flat surface (table top, etc.) the sides of which are labeled "N", "S", "E" and "W";
2. A small piece of modeling clay,
3. Pencil
4. Flashlight.

PROCEDURE/INTERPRETATION

1. Stick the pencil into the clay and place this on the table top as you see in the diagram below. Since the diagram is a plan (aerial) view the pencil will appear as a dot.

2. Have the students gather around this demonstration area. Ask them: "What direction does the Sun appear to come up?" ANS: East
   Bring the flashlight up from behind the direction of east. The light will shine on the pencil whose shadow will be cast to the west. With the Sun (flashlight) just on the eastern horizon, ask them: "At sunrise is the shadow long or short?" ANS: Long

3. Bring the Sun up to the noon (south) position. The arc that you make with the Sun should NOT pass directly over the stick but rather south of the stick. (Reason: the noon Sun is never overhead in the continental United States) During this time make sure the Sun (flashlight) shines on the pencil. Ask them: "What has happened to the length of the shadow?" ANS: It has shortened

4. What can you say about the length of the shadow at the noon position?
   ANS: The shadow is at its shortest distance because the Sun is at its highest point in the sky.

5. "At this noon position what direction does the shadow point? What direction is the Sun?" ANS: This shortest shadow points toward north because the Sun is south.

6. Move the Sun to sunset. "As the Sun moves toward sunset what happens to the length of the shadow? ANS: It grows longer.

7. Now start over again with the Sun on the eastern horizon. Take the flashlight from the eastern horizon to the noon position, to the sunset position while keeping the flashlight aimed at the pencil. Do this several times always starting at the east and moving to the west. Ask them: "Which way does the shadow of the pencil move, clockwise or counterclockwise?"
   ANS: Clockwise.

"In ancient times any tall object placed straight up and down (perpendicular) to the ground was called a gnomon (pronounced with the "g" silent) and the shadow cast from it was used as a time keeping device. As time marched on clocks were eventually invented and the movement of the hands of a clock was based on the movement of the gnomon's shadow, which as you saw was left to right as you face north. Eventually this motion was called clockwise. Thus, the hands of a clock follow the path of the gnomon's shadow.

Summary questions  Telling Time with a Stick

8. "You are lost during the daytime assume the Sun is shining brightly. You have no idea what time it is or what direction is north. What should you do?"
   ANS: Place a stick in the ground and watch its shadow.

9. "If the shadow keeps getting shorter and shorter are you in the morning hours or afternoon hours?" ANS: morning
10. "When the shadow reaches its shortest length what time is it and in what direction is the shadow pointing?"
   **ANS:** Noon, the direction is north. The Sun is opposite the shadow is located directly south.
ACTIVITY 4  Is the Earth Flat?

INFORMATION

I believe there are very few of us who have actually verified that the Earth is round, or for that matter that it actually rotates. The globes in our schools or the Apollo photographs are both secondhand pieces of evidence that could not be used as proof in a court of law. Many of us, especially our students, simply believe what we hear. Round or flat, whatever. I realize it's not a life-or-death matter, unless you happen to live .......... near the edge!

So, is the Earth flat or round? The proof for a flat Earth is obvious—it's what you see. In fact, when you are traveling on a commercial airliner at 35,000 feet the ground still appears to be flat. So how can you prove that the Earth is round when it is contrary to what we see? You must show logical conclusions for your ideas.

The following series of diagrams represents a ship that is sailing away from you.

When ancient man stood on a shoreline, he was baffled by the fact that ships appeared to vanish into the horizon. Some of the journeying mariners never returned to their native land. Those, who were left behind, not knowing the real reasons that the ships disappeared, theorized that their sea-faring comrades had sailed over the edge of the Earth to the waiting jaws of a sea monster.

When the mariners returned to their homes, those who had seen them disappear were puzzled as to how the mariners had escaped the inevitable doom awaiting anyone who attempted to sail into the horizon.

INTERPRETATION

1. Explain what ancient man witnessed.

INFORMATION

The following diagram illustrates what actually happened.
2. If you stood on the east shoreline of Lake Michigan during a clear mid afternoon day you would be able to look across the lake (to the west) and see the tops of the tall buildings in Chicago. What would you observe, regarding the buildings, if you were standing on top of a hill one hundred feet above the shoreline?
A. more of the buildings    B. less of the buildings    C. be no change in what you viewed on shore

3. Regarding question #2. What made the difference?

INFORMATION

The Four Corners of the Earth

The phrase "we have traveled to the four corners of the Earth" implies a flat square Earth. We of course know that the Earth is round; however, it appears as though there might be four corners.

"According to the Johns Hopkins University Applied Physics Laboratory (whose scientists did the research), the points are located as follows:

One high point centers over Ireland and spreads northward toward the pole. Another extends across the equator from New Guinea northward toward Japan. A third corner is south of Africa, centered about halfway to Antarctica. The fourth corner is west of South America with its high point off Peru."

*From Parade Magazine, June 8, 1997, p.15, Ask Marilyn by Marilyn Vos Savant

INFORMATION Did the Ancients Believe the Earth was Flat?

Most of us believe those who lived before Christopher Columbus thought the Earth was flat. That just isn't the case. Those who were educated were aware the Earth was probably round and those who weren't educated believed the Earth was flat. Today, most people with an education in the sciences know that Astrology is a pseudo science; however, hundreds of millions of dollars are spent every year for the casting of horoscopes.

*James Trefil says: "Actually, Greek scientists knew Earth was a sphere thousands of years before Columbus first sailed the Atlantic. That knowledge was incorporated into the book that served as the standard astronomy text in medieval universities. Columbus didn't have to convince educated men and women that he could reach the East by sailing west. His task was more practical. He had to convince them that Earth's circumference was small enough to allow him to reach China before his ships would run out of food and drinking water.

Universal belief in a flat Earth in Columbus's day is a myth—one example of a modern tendency to assume those who came before us were less able to cope with the universe. The cumulative nature of science is partly to blame. Each discovery raises new questions, which scientists answer later. Modern college students know more about physics than did Isaac Newton. Of course, that doesn't make the students geniuses. Indeed, the more I discover what ancient scientists did with primitive instruments, the more impressed I become."

*From Astronomy Magazine, August, 2000, p.40 “Rounding the Earth” by James
ACTIVITY 5 Measuring Circumference

INFORMATION Eratosthenes

In the ancient Near East, around the third century B.C., in greatest metropolis of the time was an Egyptian city called Alexandria. Here lived a man named Eratosthenes. He was an astronomer, historian, geographer, poet, philosopher, and mathematician. In addition, he was the director of great library in Alexandria. He read in a papyrus book that on June 21, in a town called Syene (located south of Alexander) vertical sticks cast no shadows at noon. A reflection of the noon Sun could be seen in the water at the bottom of a deep well. Thus, the noon Sun was at zenith (directly overhead).

He noted that on June 21, in Alexandria, the noon Sun cast a shadow.

INTERPRETATION

1. June 21 represents:

____ 2. Give the latitude for Syene.

3. Explain why was there no noon shadow at Syene; and there was a noon shadow at Alexandria

INFORMATION

Eratosthenes used a vertical post called a gnomon (NO-mun) and measured the angle of the Sun's rays to the gnomon. He found the angle to be 7°12' in Alexandria. Because of the Sun's great distance (and size) from the Earth, ALL LIGHT RAYS REACH US NEARLY PARALLEL. Eratosthenes reasoned that the Earth must be curved, because the Sun's rays were perpendicular to the Earth at Syene but made an angle with the Earth at Alexandria.

INTERPRETATION

4. If the Earth were flat what would be the angle of the Sun at Syene and Alexandria?

INFORMATION-INTERPRETATION

The angle of 7°12' is 1/50 of 360° (the circumference of a circle). Eratosthenes knew from his travels that Syene was about 5,000 stadia (850km or 510 miles) or 1/50 of the circumference of the Earth (measured around the poles instead of at the equator) from Alexandria. Thus,

\[
\begin{align*}
1 & : 5,000 \\
50 & : X
\end{align*}
\]

____ 5. What does X equal

____ 6. How many km?

____ 7. How many miles
INFORMATION
Today, the accepted measurement of the earth's circumference is 40,000km (24,888 miles). Eratosthenes measurement was very accurate, considering he used only sticks and his brain.
The diagram below illustrates the method involved. Angles are greatly exaggerated.

June 21

INTERPRETATION
8. You have just landed on a planet in another solar system. You set up a gnomon and at true noon calculate that the angle of the Sun's rays to the ground is 81°. At the same time one year later, after traveling a distance of 2,500 km's to the south you set up another gnomon and note that on this bright sunny day there is no shadow. What is the circumference of this planet?

Angles exaggerated for better understanding
ACTIVITY 6  Does the Earth Rotate?

INFORMATION

The Earth rotates. That is a simple statement we have all known since we were in early grade school. Do we really know that this true? Or are we the center of the Universe with the stars, Sun and other planets revolving around the Earth? For thousands of years the latter statement was believed to be true.

INTERPRETATION

1. We have learned that the Earth rotates (as viewed from high above the equator) from the____to the______

2. If you stand and face east and toss a piece of chalk or a ball straight into the air, where will it land?

3. If the Earth is rotating towards the east why didn't the object land behind you? Here at our latitude (40°N) the Earth is rotating nearly 800 mph. Therefore, you can't say were moving too slowly!

4. Since we are moving at nearly 800 mph, why can't we feel this speed?

INFORMATION-PROCEDURE  Pendulum

Have someone stand on a chair directly above you and hold a string with a ball (small rubber ball, ping pong ball, etc.) attached. There should be a distance of at least 18 inches between the object and your head. Have this person swing the ball back and forth like a pendulum. Look straight up and adjust yourself in the chair so that the object is going across your eyes. Now slowly turn 90° counterclockwise (right), keeping your eyes fixed on the object.

INTERPRETATION

5. What direction did the pendulum appear to move as you turned?
   A. Clockwise  B. Counterclockwise

MATCHING

6. You are now 90° from your starting point. What is the direction of swing? A. across your eyes

7. Turn another 90°. What is the direction of swing B. up and down your nose

8. Turn another 90°. What is the direction of swing?  

9. Did the pendulum change direction or did you?
INFORMATION       Foucault (foo-KOH) Pendulum

In 1851, a French physicist-Jean Foucault (1819-1868), suspended a free-swinging pendulum from the interior of the dome of the Pantheon in Paris. The dome was very high, allowing the slender wire to be over 65 meters (219 feet) long.

At 10 am Foucault drew the heavy copper ball (28 kilograms or 62 lbs) to one side, tied it securely with a thin cord, then burned the cord to set the pendulum swinging smoothly in a north to south plane. Underneath it was a large circular table with a ridge of sand on its edge. As the pendulum swung, a pin attached to the bottom of the ball would make a mark in the sand. Gravity pulled the pendulum toward the center of the Earth; it couldn't act to change the plane in which the pendulum swung. It was apparent from the marks in the sand that the pendulum was deviating. The pendulum swung in a plane fixed in space while the Earth rotated underneath. To the spectators watching Foucault's demonstration, the plane in which the pendulum swung appeared to rotate slowly 11.25° per hour in a clockwise direction which is opposite to the direction of Earth's rotation. In reality, it was the room that was moving, not the pendulum! The rotation of the Earth was proven.

INFORMATION      Pendulum at the North Pole

The Foucault Pendulum is easiest to understand if it is set swinging at the north pole. Then as the Earth rotates under the pendulum, its plane appears to make one clockwise rotation in 24 hours or 15° per hour. At the equator, the plane of the pendulum doesn't appear to rotate relative to the Earth.

INFORMATION-INTERPRETATION  Museum Pendulum's

The next time you are at a major museum like the Museum of Science and Industry in Chicago, go visit the Pendulum display. Note the direction of the swing; then come back to the display an hour or two later.

_____ 10. A few hours later the pendulum will have appeared to shift to your...  A. left    B. right

_____ 11. The direction of the pendulum will be.....A. clockwise   B. counterclockwise

_____ 12. What happened in regards to the plane of the pendulum's swing during the few hours that you were away?
   A. It actually moved counterclockwise
   B. It actually moved clockwise
   C. The room containing the pendulum actually moved counterclockwise
   D. The room containing the pendulum actually
ACTIVITY 7    Why Can't We Feel the Earth Rotating?

INFORMATION: Latitude and Longitude

*Latitude Lines* are the lines on a globe that are parallel to the equator. They measure in degrees your location on the Earth north or south of the Equator. Show them on a globe that we are located at about 40° north of the Equator. The North Pole is considered to be 90° north of the Equator; therefore, we live about half between the Equator and the North Pole. *Longitude Lines* are lines that are "up and down" from the North Pole to the South Pole.

PROCEDURE
1. "Here at our latitude we are moving about 800 mph. When you drive in your car you may go 60 miles per hour. If you were racing at Indianapolis or Daytona you might be driving at 225 miles per hour. Jet airplanes, the kind we fly when we go on a far away vacation, travel at 400 mph. Right now, the Earth, here at our latitude, is moving 800 mph."

2. "Sit perfectly still, don't move a muscle. Do you feel the earth moving at 800 mph? Since the Earth is moving so fast how come we don't feel it?" *ANS:* Answers will vary.

3. "Let's suppose you are in a car stopped at a stop light. A car pulls up next to you and also stops for the light. What does the speedometer say in your car?" *ANS:* Zero

4. "What is your speed relative to the other car?" *ANS:* Zero

5. "The light turns green and you accelerate to 30 mph. The car next to you also accelerates to 30 mph. What does the speedometer say in your car?" *ANS:* 30

6. "What is your speed relative to the car that is traveling next to you at the same speed?" *ANS:* zero

*You are neither ahead or behind the car that is next to you.* In a sense it's like it was when you were both stopped at the stoplight. Your speed relative to each other was zero and still is zero.

7. "What is the speed of the air inside your car (assuming the windows are rolled up) as you travel down the highway at 30 mph?" *ANS:* 30 mph

8. "If the car is moving at 30 mph, the air inside the car will be moving with you at the same speed. However, your speed relative to the air in the car is zero.

9. Ask them: "Let's pretend we are in a car traveling down the road at 60 mph with the windows rolled up. Would you feel the air inside the car blowing against your face?" *ANS:* No. "How come?" *ANS:* The air inside the car is moving with you at 60 mph; therefore you wouldn't feel it against your face. In fact everything in the car is moving with you at the same speed.

10. Conclusion: The reason we can't feel the Earth rotating is: Everything (air, your desks, this room, this school, etc.) is moving with us at the same speed. Since everything is moving with us at the same speed we don't feel a thing just like we can't feel the air moving against our face when we traveling down the highway. Therefore, we do not feel the Earth moving because there is no frame of reference. In other words when you are going down the road you feel the vibration of the road and you see telephone poles going past you. As we sit here in class we don't feel like we're moving since everything around us is moving with us at the same speed
ACTIVITY 8  Earth Revolution/Measuring Nearby Stellar Distances

INFORMATION  The Earth: Center of the Universe?
In the previous problem sets we have proved that the Earth is round and it rotates around an imaginary axis giving us our days and nights. Yet the question still remains: Is our Solar System geocentric (Earth-centered) or heliocentric (Sun-centered)? How do we explain the fact that the noon Sun is at its highest point during the summer and its lowest point during the winter? If the Earth is indeed orbiting the Sun how do we prove it?

INTERPRETATION  Parallax

1. Ancient man noted parallax—the difference in apparent location of an object as seen from two different points. Hold your thumb so that it is about a 30 cm (one foot) from your nose. Close your left eye and look at your thumb with your right eye. Now close your right eye and open your left eye. Then close your left eye and open your right eye. Repeat these steps several times. Did your thumb appear to move?

2. Did it really move? This is called parallax.

3. Move your thumb to arm’s length. Open one eye and close the other and then repeat this procedure. Was the apparent change in shift greater or less than when it was 30 cm’s away?

4. What can you conclude about interpretations 1-3 regarding the change in the shift?

INFORMATION  Proof of Revolution
Ancient man did not have conclusive proof that the Earth went around the Sun, although some scholars at that time suspected it. The failure to detect a parallax led many to reject the notion that the Earth was orbiting the Sun, since it seemed obvious that if it were, the stars would appear to shift back and forth as a result of our motion. Eventually the heliocentric theory won out, but stellar parallax was still undetected.

It wasn’t until the invention of the telescope that early astronomers were able to prove Earth’s revolution. The telescope enabled us to see nearby red dwarf stars that were otherwise not visible. Over a period of six months astronomers were able to see the apparent shift of these nearby star relative to the background stars. The conclusion was either the star is moving back and forth or the Earth is moving from one position to another every six months. Stars do not act in this manner, therefore, the Earth must be moving.

Diagram A

```
1  2  3  4  5  6  7  8  9  10  11  12  13
  * * * * * * * * * * * * * * *
     X

EARTH A  SUN  EARTH B
```

19
INFORMATION

Diagram A is greatly exaggerated but it shows the principle of parallax. The difference between Earth position A and B is six months. In reality the angle of parallax for nearby stars is measured in arc seconds rather than degrees as illustrated. One degree is made up of 60 parts called minutes. Each minute is divided into 60 parts called seconds. Therefore, the angle of parallax is at best a few arc seconds not the tremendous angle shown in Diagram A.

Here's another way to look at Diagram A. Earth A is your left eye; Earth B-right eye; Sun-nose; Star X-thumb.

INFORMATION Using Parallax to Measure Nearby Stellar Distances

In 1838, parallaxes were detected independently by F.W. Bessel, F. G. W. Struve and T. Henderson. Each observed a different nearby star. The reason stellar parallaxes had defied earlier observers became obvious: even for the closest stars, the maximum shift in position was much less than one second of arc! The stars are simply much farther away than the ancient astronomers had dreamed possible.

The distance to a star can be determined by measuring the star's parallax. The parallax (p) of s star is half the angle through which the star's apparent position shifts as the Earth moves from one side of its orbit to the other. If the angle "p" is measured in seconds of arc, then the distance "d" to the star in parsecs is given by the equation

\[ d = \frac{1}{p} \]

A Parsec equals 3.26 light years
A Light Year equals 10^{13} km (6 x 10^{12} miles)

INTERPRETATION

5. F.W. Bessel, using a telescope found the parallax of red dwarf star 61 Cygni to be .33 arc second. How far away was/is this star in light years?

\[ d = \frac{.33}{1.00} \]

3 parsecs

6. The nearest star, Proxima Centauri, has a parallax of .77 arc seconds. How far away is it in light years? The annual parallax motion of Alpha (Proxima) Centauri, the nearest to the Sun, is comparable to the angular diameter of a dime as seen from a distance of about two miles, obviously a very small angle.

7. Barnard's Star has a parallax of .55 arc seconds. How far away is it in light years?

8. A star is 6.52 light years from Earth (Sun). How many arc seconds does it cover?

9. Wolf 359 has a parallax of .42 arc seconds. How far away is it in light years?

10. Sirius has a parallax of .38 arc seconds. How far away is it in light years?

INFORMATION

Because parallaxes smaller than about 1/20 arc second are difficult to measure accurately from Earth-based telescopes, the parallax method gives reliable distance only for stars nearer than about 20 parsecs (65 light years). There are nearly 2,000 stars within this range, half of which have had their parallaxes measured with high precision. Most of these nearby stars are far too dim to be seen with the naked eye. In contrast, the majority of the familiar bright stars in the nighttime sky are too far away to exhibit parallaxes mea
ACTIVITY #9: Precession...Another Earth Motion

Objective: Student will determine that Earth moves about its axis in two ways.

Materials: S.P.L.

PROCEDURE / INTERPRETATIONS:

So far you should know that the Earth is: round; rotates about its axis; and revolves around the Sun. Did you know that the Earth has another motion?

The Vernal Equinox represents the first day of spring, which is March 21. About 4,000 years ago the Babylonians noted that on this date, at dawn, the Sun was in the zodiac constellation of Aries.

1. On your S.P.L., dial March 21 at 5:30 am (approximate sunrise time) face south. Follow the ecliptic line (path of the Sun, zodiac) until it intersects the eastern horizon. The Sun will rise in the zodiac constellation of (ANS: PISCES)

2. From 4,000 years ago to 2,000 years ago the Sun was in Aries. Where is Aries today, on March 21? (ANS: BELOW THE EASTERN HORIZON)

3. What direction are the zodiac signs moving? (east, west) (ANS: EAST)

4. Two thousand years from now on March 21, the Sun will rise in the zodiac constellation of (ANS: AQUARIUS)

5. What direction is the vernal equinox (Sun) moving? (east, west) (ANS: WEST)

INFORMATION

We know that the stars, for all practical purposes, represent fixed positions on our celestial sphere. The apparent rising and setting of the celestial sphere is caused by the Earth's rotation. The fact that the celestial sphere drifts westward until it returns to its starting point a year later is an indication of the Earth's revolution around the Sun. Therefore, this apparent continuous shift of the vernal equinox must indicate another Earth motion.

As you have seen the zodiac will shift eastward while the vernal equinox (Sun) drifts westward through the zodiac. The Earth, like a top, wobbles as it rotates. This is due to the gravitational pull of the Sun and Moon. One wobble (precession cycle) takes about 25,800 years.

The apparent westward motion of the Sun through the zodiac is very slow—too slow to be detected in an observer's lifetime. Thus, it would take many lifetimes of recorded observations to note this subtle (precession) change.

We noted earlier that the Babylonians found the vernal equinox in Aries and yet Hipparchus, several centuries later, discovered that it had moved westward in Aries. At the time of Jesus, the Sun was entering the zodiac sign of Pisces. This continuous change became known as the precession of the equinoxes. Today, we refer to this Earth motion as simply precession.
INFORMATION  Will Polaris Always be the North Star??

Because of precession, the North Pole axis will trace a circle counterclockwise in the northern sky while the Earth's south pole axis traces a circle clockwise in the southern sky. Today, there is a star located almost directly above the North Pole. It is called the North Star. Directly above the South Pole there is no star; therefore, there is no south star. However, between the years 7,000 A.D. and 14,000 A.D. many bright stars in the constellations of Puppis, Carina and Vela will qualify.

At the present time, Polaris our North Star lies on the precessional circle (see diagram at right). By the year 4,000 A.D. the North Pole axis will point to the head star of Cepheus. This star will then be the "north star." In the year 10,000 A.D. the North Pole axis will point close to Deneb, a star in the constellation of Cygnus (Northern Cross/Swan); by the year 14,000 it will point near Vega in the constellation of Lyra. Both stars are much brighter than Polaris; however, they will be less than satisfactory since each lays several degrees off the circle of axial precession.

There are other changes that are caused by precession. Spring arrives 20 minutes earlier each year relative to the stars as the vernal equinox slides westward along the ecliptic (zodiac). Thirteen thousand years from now, which is one-half of the precessional cycle, the Winter Triangle (Betelgeuse, Procyon and Sirius) will be the summer triangle and the Summer Triangle (Deneb, Altair and Vega) will be the winter triangle!

This is one proof of many that Astrology is nonsense. Why? Because the birth signs (zodiac constellations) listed in a horoscope are not accurate. They don't match up with the zodiac sign in which the Sun is currently located due to precession.
6. What was the name of the North Star 6,000 (4,000 B.C.) years ago?
   **ANS:** Thuban

7. What constellation will contain the North Star 2,000 years from now (4,000AD)?
   **ANS:** Cepheus

8. In the precession cycle, how long does it take the Sun to move through a zodiac constellation? Let's assume that all zodiac signs are the same width, which of course they are not.
   **ANS:** 2,150

9. How many degrees make up a zodiac constellation? According to astrologers there are 12 zodiac constellations.
   **ANS:** 30

10. How many years will it take the Sun to move one degree in its journey through a constellation?
    **ANS:** 71.6 yrs.

11. What is the direction of the Earth's wobble (precession)? (clockwise, counterclockwise)
    **ANS:** Counterclockwise
**ACTIVITY 10:** Precession/Changing Sun Signs/Fallacy of Astrology

**INFORMATION** The Zodiac Constellations (Sun Signs)

In the chart below are the zodiac constellations and their corresponding dates as listed by Astrologers not Astronomers. The dates represent the entrance and exit of the Sun for each constellation. These dates were somewhat valid between 2,000 B.C. and the birth of Christ.

- **Pisces** Feb. 19 - Mar. 20
- **Aries** Mar. 21 - Apr. 19
- **Taurus** Apr. 20 - May 20
- **Gemini** May 21 - Jun. 20
- **Cancer** Jun. 21 - Jul. 22
- **Leo** Jul. 23 - Aug. 22
- **Virgo** Aug. 23 - Sep. 22
- **Libra** Sep. 23 - Oct. 22
- **Scorpius** Oct. 23 - Nov. 21
- **Sagittarius** Nov. 22 - Dec. 21
- **Capricornus** Dec. 22 - Jan. 19
- **Aquarius** Jan. 20 - Feb. 18

The zodiac sign you were born under is not the sign you see in the night sky on your birthday, but rather, the sign the Sun was located on the day of your birth.

1. Let's suppose you were born on December 28. According to the chart above your Sun sign should be (ANS: CAPRICORNUS)

2. Using your S.P.L. Dial December 28, 8:00 am. (sunrise time) The Sun is really in the constellation of (ANS: SAGITTARIUS)

3. What’s wrong with the dates listed above? (ANS: Because of precession all zodiac signs have shifted to the east. Remember Zodiac signs shift every 2,150 yrs.

**INFORMATION** Actual Birth Sign

The chart below represents a somewhat accurate reflection of the actual Sun entrance and exit dates of each zodiac constellation for our time.

- **Pisces** Mar. 12 - Apr. 18
- **Aries** Apr. 19 - May 14
- **Taurus** May 15 - Jun. 19
- **Gemini** Jun. 20 - Jul. 20
- **Cancer** Jul. 21 - Aug. 9
- **Leo** Aug. 10 - Sep. 15
- **Virgo** Sep. 16 - Oct. 30
- **Libra** Oct. 31 - Nov. 22
- **Scorpius** Nov. 23 - Nov. 29
- **Sagittarius** Dec. 18 - Jan. 18
- **Capricornus** Jan. 19 - Feb. 15

4. So, that should settle it, right? Dial Nov. 30, 7:30 am. Look at the intersection of the ecliptic and the southeast horizon. Name the constellation that is closest to the ecliptic. (ANS: OPHIUCHUS) Between Nov. 30 and Dec. 17 the Sun is indeed in Ophiuchus; not Scorpius. Write Ophiuchus and its dates in the blank between Scorpius and Sagittarius on the chart above.

**INFORMATION** How Many Zodiac Signs?

Astrologers would like you to believe twelve. Twelve was a sacred number in ancient times. This probably occurred because there were 12 cycles of the Moon plus 12 extra days to fill out ancient man's year. Also, 12 is easily divisible by 6, and 6 was ancient man's favorite number. A zodiac sign is supposed to be any star of a star pattern that is within 8° of the ecliptic. If you examine the ecliptic you will see there are actually 24 constellations that should be considered as zodiac constellations.
INFORMATION

<table>
<thead>
<tr>
<th>24 Zodiac Signs</th>
<th>Libra</th>
<th>Pisces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquarius</td>
<td>Cetus</td>
<td>Scutum</td>
</tr>
<tr>
<td>Aries</td>
<td>Corvus</td>
<td>Serpens</td>
</tr>
<tr>
<td>Auriga</td>
<td>Crater</td>
<td>Sextans</td>
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<tr>
<td>Cancer</td>
<td>Gemini</td>
<td>Taurus</td>
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<tr>
<td>Canis Major</td>
<td>Hydra</td>
<td>Virgo</td>
</tr>
<tr>
<td>Capricornus</td>
<td>Leo</td>
<td></td>
</tr>
</tbody>
</table>

INFORMATION

Astrology: Fact or Fiction?

1. For this to be an exact science the zodiac signs should be equal in size. The "twelve" zodiac signs are not equal in size. They range from an apparent 56° for Virgo to only 14° for Cancer. Since this is the case how can astrologers assign 29 to 32 days for the time the Sun spends in each sign? The true amount of time ranges from 7 days for Scorpius to 45 days for Virgo.

2. Astrologers tell us the zodiac constellations are located 8° either side of the ecliptic line. Since this is the case we do not have 12 zodiac signs but 24. However, we don't see 24 zodiac constellations listed in a horoscope. We, of course, are only talking about the naked eye constellations. How about all of the stars that exist within this boundary that we can't see? If we use binoculars we can see many more stars in this area; aren't they just as important?

3. How about the energy coming from the stars of the zodiac constellations; do they have an affect on humans? The answer is absolutely not! These stars are too far away for their energy to affect us directly.

4. How many planets exist in our sky? The answer, of course, is eight. Why don't the astrologers use 8 planets when they cast a horoscope? They only use five. The reason: In ancient times they only knew of 5 planets, which to them were gods. They had no knowledge of Uranus, discovered in 1781; Neptune, discovered in 1846 and Pluto, discovered in 1930.

5. How do planets affect our lives here on Earth? They don't! The light coming from the planets is reflected sun light. We are (usually) born in enclosed room, therefore, the light from the planets could not affect us. The gravity of the planets has absolutely no affect on us; therefore, the position of the planets has no bearing on the way we are.

6. Planets do not travel through the stars of the zodiac. The stars are very far away. If we had an orange to represent the Sun, Pluto would be a one-half pencil dot located 40 meters away. The nearest star to us would be another orange located in Indianapolis, Indiana.

7. How about the characteristics of each zodiac sign? For instance a Libra is supposed to be "well balanced, a good judge of things," etc. In 1975, a survey was conducted in regards to newspaper horoscopes. In one month the researchers found what was written for Gemini on one day was the same thing written for Pisces two weeks later! This astrologer simply shuffled things around.

8. Finally, what about precession? Why haven't the present day astrologers changed the dates for the Sun signs? The reason: If they do then it sends a message that all of this garbage people having been paying big bucks for in the past was all in error. No astrologer wants to put doubt on his or her profession—they'll lose money. Besides the everyday person on the street has no concept of precession, the distance of stars, the number of planets, etc. So who made up these statements? People who lived thousands of years ago, who were trying to rip off the ignorant people of their times. Amazingly, it still goes on today to the tune of several hundred million dollars a year!
**LESSON 2: Circumpolar Star Finder**

**Vocabulary**

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumpolar</td>
<td>Stars and Constellations that go around Polaris. They never go below the horizon</td>
</tr>
<tr>
<td>Clockwise</td>
<td>The direction the hands of a clock turn</td>
</tr>
<tr>
<td>Constellation</td>
<td>Shapes or patterns that stars seem to make</td>
</tr>
<tr>
<td>Counterclockwise</td>
<td>Opposite the direction the hands of a clock turn</td>
</tr>
<tr>
<td>Polaris</td>
<td>Called the North Star it is a star located directly above the Earth’s North Pole. Since the North Pole doesn’t move neither does the North Star; thus, always showing us the direction of North.</td>
</tr>
<tr>
<td>Revolution</td>
<td>Orbiting around another object</td>
</tr>
<tr>
<td>Rotation</td>
<td>Turning on one’s axis</td>
</tr>
</tbody>
</table>
Circumpolar Star Finder

ACTIVITY 11  Five Circumpolar Constellations

INFORMATION  Circumpolars

Circumpolar refers to the five naked eye visible constellations that can be found rotating around the North Star (Polaris) in the northern sky. These constellations are visible (if it isn't cloudy) every night of the year. They never ever go below the horizon.

The fastener of the Circumpolar Star Finder will represent the North Star. In the northern sky here in Indiana the North Star is located directly north and about half way up from the horizon.

It is important that the students understand they must face north to see these constellations. It is important that they hold the Circumpolar Star Finders level with the horizon. Any other orientation will yield faulty answers/information.

MATERIALS:

1. Circumpolar Star Finder Page (supplied by Planetarium)
2. Fasteners one per student  (You supply)
3. Scissors

PROCEDURE
A. Have the students cut out the two diagrams from the Circumpolar Star Finder Page
B. Using their fastener have hem fasten the star wheel to the second diagram

1. How many constellations are on the star wheel?
   ANS: Five

2. Rotate the star wheel one full turn. Do any of the five constellations go below the horizon
   ANS: No

3. Set the circumpolar Star Finder for March 1 at 9:00 pm. Aligning the March arrow with 9:00 pm does this. The arrow between March and April represents the middle of the month. In this case it would be March 15. However, we are using March 1 for this problem. Where is the Big Dipper compared to the North Star? (A. left B. right  C. directly above  D. directly below)
   ANS: B Right

4. How many stars are in the Big Dipper?
   ANS: Seven

5. Another name for the Big Dipper is........
   ANS: Big Bear or Ursa Major
In the diagram to the right the two stars of the Big Dipper Dubhe and Merak are called the pointers, because a line through them will point to other stars and constellations.

6. A line from the pointers will take us to a star called....
   ANS: Polaris the North Star

7. This star is in the constellation of....
   ANS: Little Dipper or Ursa Minor

8. How many stars are in the Little Dipper
   ANS: Seven

9. A line from the pointers through Polaris will take us to the constellation of
   ANS: Cepheus the King

10. T/F The constellation referred to in the above question looks like a crooked house.
    ANS: True

11. How many stars are in Cepheus the King?
    ANS: Five

12. Draw a pretend line from the last star in the handle of the Big dipper through Polaris and keep going.... what constellation will you run into?
    ANS: Cassiopeia

13. What letter does this look like?
    ANS: “W”

14. How many stars make up the constellation of Cassiopeia?
    ANS: Five if you draw a “W;” or Six if you draw a chair

15. Take the two pointers and flip them over in the direction of Polaris. You are now at the beginning (actually the end) of a constellation called...
    ANS: Draco the Dragon

16. Draco the Dragon wraps part way around the constellation of........
    ANS: Little Dipper

17. Just before Draco gets to Cepheus it turns back. The head of the Dragon can be found near the.........(A. zenith,  B. Horizon)
    ANS: B Horizon
Motion of the Northern Sky

INFORMATION/INTERPRETATION

We learned in previous lessons that the Earth turns toward the east; therefore, the stars (Sun), planets and the Moon, which are located in our southern sky appear to move the opposite way or towards the west.

1. How does the northern sky appear to move?
   A. clockwise   B. counterclockwise
   **ANS:** B Counterclockwise

2. Dial March 1 for 3:00 am. Where is the Big Dipper compared to Polaris?
   A. left   B. right   C. above   D. below
   **ANS:** C Above

3. In order for the Big Dipper to get to this new position from 9:00 pm it appeared to travel
   A. clockwise   B. counterclockwise
   **ANS:** B Counterclockwise

4. Why did the Big Dipper appear to move counterclockwise?
   **ANS:** Because the area near the North Pole moves counterclockwise when viewed from the North Star.

Now see if you can find the other circumpolar constellations using the rules that you followed earlier. You will see that they have also moved counterclockwise around the North Star (Polaris).

Move the wheel around to March 1 at 9:00 pm. Once again note that the Big Dipper is directly right (in the direction of northeast) of Polaris. Move the wheel to June 1 at 9:00 pm. This is close to the beginning of summer vacation.

5. Where is the Big Dipper on June 1 at 9:00 pm compared to Polaris?
   (A. left   B. right   C. above   D. below)
   **ANS:** C above

6. What caused the Big Dipper to change position from March 1 at 9:00 pm to June 1 at 9:00 pm?
   (A. Earth rotation   B. Earth revolution)
   **ANS:** B Earth Revolution 90 days = 90°

CONCLUSION

The Circumpolar Star Finder is a very useful tool because it can be used for any time of day and for any day of the year. Just for fun, have the students dial in their birth date for 9:00 pm. Explain that this is the position of the Northern Sky on their birthday at 9:00 pm. Someone born on the 7th of May as an example would use the location between the May 1st arrow and the middle (May 15th) arrow.

Students can keep their Circumpolar Star Finders. You will have new ones each year.
LESSON 3: Reasons for the Seasons
Vocabulary

**Celestial Equator**
Imaginary projection of the Earth's equator into our sky.

**Ecliptic**
The imaginary plane the Earth orbits as it goes around the Sun. The imaginary line that connects the Earth and all the planets to the Sun.

**Equinox**
It refers to the two days when the Earth experiences *equal days and equal nights* or *12 hours of daylight and 12 hours of darkness* everywhere on the Earth.

**Land of Midnight Sun**
A location between 66.5°N and the 90°N where the Sun can be viewed for 24 hours; thus, a circumpolar Sun.

**Rotation**
Viewed from Polaris it is the counterclockwise turning of the Earth around its axis. One rotation of the Earth equals approximately 24 hours of solar time; one hour equals 15° of rotation.

**Revolution**
Viewed from Polaris, the Earth orbits or revolves around the Sun counterclockwise (as viewed from Polaris) once every 365.25 days; one day equals about 1° of revolution.

**Seasons a tilted Earth orbiting our sun produces the four seasons.**

**Solstice**
It refers to the time that the Sun stops increasing or decreasing its angular height (altitude) on the observer's meridian. This occurs on June 21 and December 21 respectively.

**Tilt of Earth**
The Earth is tilted 23.5° from an imaginary line (plane of the ecliptic) between the Earth and the Sun.

**Tropics**
Tropic of Cancer 23.5°N of Equator; Tropic of Capricorn 23.5°S of Equator.

**Vernal**
Refers to spring, a time to "green up" as in Vernal Equinox.

**Zodiac**
Constellations located along the ecliptic.
LESSON 3 Reasons for the Seasons

ACTIVITY 13 Why We Have Seasons

OBJECTIVE

The student should be able to explain and demonstrate the Earth has seasons because it is tilted and revolves (orbits) around the Sun.

MATERIALS:

1. The smallest globe you can find or a ping pong ball with the equator drawn and a darning needle sticking through it to represent the axis of the Earth.

2. A light fixture with a 75 watt bulb. The demonstration should follow the diagram below.

   NOTE: the summer position is farther from the Sun then the winter position...that's not a mistake!

![Diagram showing the Earth's orbit and seasons]

PROCEDURE/INTERPRETATION

1. What three things does this diagram illustrate? ANS: The Earth is TILTED, it ORBITS (REVOLVES) counterclockwise around the Sun, The Earth is closer to the Sun during our winter and farthest from the Sun during our summer.

2. During our (N. Hemisphere) summer is the North Pole pointed toward the Sun or away? ANS: Toward

3. During our winter is the North Pole pointed toward the Sun or away? ANS: Away
4. Which season, summer or winter, will the Sun be the highest in our sky? **ANS:** Summer

5. Which season, summer or winter, will the Sun be the highest in our sky? **ANS:** Winter

6. Which season is the Earth farthest from the Sun? **ANS:** Surprisingly it's during our summer that the Earth is at its greatest distance from the Sun. Because of this the Sun's gravitational pull is less and the Earth is moving slower in its orbit. During our winter the Earth is at its closest distance to the Sun and we are moving faster in our orbit; therefore, Summer is actually two days longer than winter.
ACTIVITY 14  

Seasons

INFORMATION  Vocabulary and It's Application

**Rotation**  Viewed from Polaris it is the counterclockwise turning of the Earth around its axis. One rotation of the Earth equals approximately 24 hours of solar time; one hour equals 15° of rotation.

**Revolution**  Viewed from Polaris, the Earth orbits or revolves around the Sun counterclockwise (as viewed from Polaris) once every 365.25 days; one day equals about 1° of revolution.

**Tilt of the Earth**  The Earth is tilted 23.5° from an imaginary line (plane of the ecliptic) between the Earth and the Sun.

**Solstice**  (sol, the Sun - sistere, to stand still) It refers to the time that the Sun stops increasing or decreasing its angular height (altitude) on the observer’s meridian. This occurs on June 21 and December 21 respectively.

**Equinox**  (equi, equal - nox, night) It refers to the two days when the Earth experiences equal days and equal nights or 12 hours of daylight and 12 hours of darkness everywhere on the Earth.

**Summer Solstice  June 21**  The noon Sun on June 21 is at its farthest point north which places it directly above the Tropic of Cancer, 23.5° north of the equator. This results because the North Pole is tilted toward the Sun. The lowest latitude to receive 24 hours of daylight (circumpolar Sun) is 66.5°N. This latitude circle is known as the **ARCTIC CIRCLE**. The **Land of the Midnight Sun** is located between 90°N and 66.5°N. People living in this area will experience the Sun being up in the sky for 24 hours.

In the northern hemisphere this is the longest day (greatest amount of daylight hours) of the year. Thus, the days are long and the nights are short. The Earth is at its **GREATEST DISTANCE FROM** the Sun at 94,500,000 miles. After June 21 the noon Sun appears lower (to travel south) and the amount of daylight hours decreases.

**Fall (Autumnal) Equinox  September 23**  The Sun at noon is directly above the equator, crossing it from north to south. The Sun will rise directly east and it will set directly west. On this day the Earth is divided in half from pole to pole with daylight and darkness; thus, there are 12 hours of daylight and 12 hours of darkness everywhere on the Earth. The axis of the Earth is neither toward or away from the Sun. This is the date when the Sun sets (traveling along the horizon) for those living at the North Pole and rises for those living at the South Pole. The Sun will now stay below the equator until March 21.

**Winter Solstice  December 21**  The noon Sun on December 21 is at its farthest point south which places it directly above the Tropic of Capricorn, 23.5° south of the equator. This results because the North Pole is tilted away from the Sun. The lowest latitude to receive 24 hours of daylight (circumpolar Sun) is 66.5°S. This latitude circle is known as the **ANTARCTIC CIRCLE**. The **Land of the Midnight Sun** is located between 90°S and 66.5°S. People living in this area will experience the Sun being up in the sky for 24 hours.

In the northern hemisphere this is the shortest day and longest night of the year. In the southern hemisphere it is the longest day and the shortest night of the year. After December 21, the noon
Sun appears to travel north (along the celestial meridian); therefore, as each day passes the Sun appears higher in the southern sky at noon. After December 21, in the northern hemisphere, daylight hours start to increase. The Earth is at its **CLOSEST DISTANCE** to the Sun at 91,500,000 miles.

*Spring (Vernal) Equinox March 21* (Vernal is Latin for green) The Sun at noon is directly above the equator, crossing it from south to north. Once again, the Sun will rise directly east and it will set directly west. The Earth is divided in half from pole to pole with daylight and darkness; thus, there will be 12 hours of daylight and 12 hours of darkness everywhere on the Earth. The axis of the Earth is neither towards the Sun or away. This is the date when the Sun sets (traveling along the horizon) for those living at the South Pole and rises for those living at the North Pole. From this date the Sun will be above the equator until September.

**Objective:** Student will use a diagram to determine seasonal positions of the earth and reasons for changing daylight hours.

**PROCEDURE / INTERPRETATIONS:**

Use **DIAGRAM A** and the previous information to answer questions 1 through 14.

---

**DIAGRAM A**

1. On **DIAGRAM A**, draw arrows showing the direction of Earth’s orbit. Along the arrows, write the name of the season, which occurs during this portion of Earth’s orbit.

2. Which two positions have equal days and nights? *(ANS: B, D)*

3. Which position represents when the Sun crosses the equator from north to south? *(ANS: B)*

4. Which position represents the Sun directly overhead at the Tropic of Cancer? *(ANS: A)*

5. Which position represents the Sun directly overhead at the Tropic of Capricorn? *(ANS: C)*
6. Which position represents the Sun crossing the equator from south to north? (ANS: D)

7. Which position represents the Autumnal Equinox? (ANS: D)

8. Which position represents December 21, the Winter Solstice? (ANS: C)

9. Which position represents sunset for people at the North Pole? (ANS: B)

10. Which position established the Tropic of Cancer and the Arctic Circle? (ANS: A)

11. Which position represents the shortest day of the year for those in the northern hemisphere? (ANS: C)

12. Which position(s) represent(s) a due east sunrise and a due west sunset? (ANS: B, D)

13. After which position do daylight hours start to increase? (ANS: C)

14. Why does the equator stay around the same temperature all year when the rest of the Earth’s areas generally undergo a slight to great change in temperature? (ANS: REGARDLESS OF THE TILT, THE EQUATOR RECEIVES MORE DIRECT SUNLIGHT FOR LONGER PERIODS OF TIME THAN THE OTHER PLACES ON EARTH)
ACTIVITY 15: Seasonal paths of the Sun (a three part activity)

Objective: Student will use diagrams and the S.P.L. to determine the path of the sun during different seasons at different locations on the earth.

Materials: S.P.L., scrap paper

PART 1: Use DIAGRAMS B and C to answer questions 1 through 10. Lines T, Q, and R represent the PATH OF THE SUN for the beginning of each season. You are standing at the center (intersection) of the E-W and N-S direction lines. Line X would be the path of your string on your S.P.L. DIAGRAM C represents the path of the Sun (facing south) for the four seasons.

---

Which line represents the noon Sun's position...

1. on the first day of summer? ____T____
2. on the first day of winter? ____R____
3. on the first day of spring? ____Q____
4. on the first day of fall? ____Q____

Which line represents...

5. the position of the equator? ____Q____
6. the celestial meridian? ____X____
7. the Tropic of Cancer? ____T____
8. the Tropic of Capricorn? ____R____
9. the shortest day of the year? ____R____
10. the longest day of the year? ____T____

11. T/F At noon the Sun is at it's highest point above the horizon.

ANS: True
12. Which Sun path has the highest noon position for the Sun? T
   **ANS:** T

13. Which Sun path has the lowest noon position for the Sun? R
   **ANS:** R

14. Which Sun path will have the shortest noon shadow? Q
   **ANS:** T

15. Which Sun path will have the longest noon shadow? R
   **ANS:** R

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16. What direction does the Sun appear to come up and set during winter? NE-NW
   **ANS:** SE-SW

17. What direction does the Sun appear to come up and set for the first day of spring/fall? SE-SW
   **ANS:** E-W

18. What direction does the Sun appear to come up and set during summer? NE-NW
   **ANS:** SE-SW

19. What direction does the Sun appear to come up and set for November 15? SE-SW
   **ANS:** SE-SW

20. What direction does the Sun appear to come up and set for February 15? NE-NW
   **ANS:** NE-NW

21. What direction does the Sun appear to come up and set for May 15? NE-NW
   **ANS:** NE-NW

22. What direction does the Sun appear to come up and set for August 15? NE-NW
   **ANS:** NE-NW

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23. What happens to the height (altitude) of the noon Sun after the first day of Summer (June 21)? In other words, after June 21 (July, August, etc.) does the noon Sun stay at the same height or does it get lower or does it get higher?
   **ANS:** Lower

24. After June 21 (Summer) do the daylight hours increase or decrease. In other words is there more or less daylight to play outside during the evening?
   **ANS:** Less Daylight Hours

25. What happens to the height (altitude) of the noon Sun after the first day of Winter (December 21)? In other words, after December 21 (January, February, etc.) does the noon Sun stay at the same height or does it get lower or does it get higher?
   **ANS:** Higher

26. After December 21 (Winter) do the daylight hours increase or decrease. In other words is there more or less daylight to play outside during the evening?
   **ANS:** More Daylight Hours
PART 2:
You will need to use your S.P.L. for questions 11 - 14. Remember that the dashed line (ecliptic) shows the path not only of the stars and Moon at night, but also the path of the Sun during the day. The solid line is your celestial equator, or the Earth's equator projected out into space.

27. Dial March 21 at noon. Face South. Where should the noon Sun be found with respect to the celestial equator? (ANS: ON THE CELESTIAL EQUATOR) Why should this make sense? (ANS: THE SUN IS DIRECTLY ABOVE THE EQUATOR ON THE SPRING (VERNAL) EQUINOX)

28. Lay your S.P.L. on the desk and place a small piece of paper on the disk just above the ecliptic where it crosses your celestial meridian. Move the disk to the left until the piece of paper meets the horizon. In what direction will the Sun rise on March 21? (ANS: DIRECTLY EAST) Move the disk to the right until the piece of paper meets the horizon. In what direction will the Sun set on March 21? (ANS: DIRECTLY WEST) This is the same as which line in diagrams B and C of part 1? (ANS: Q)

29. Dial June 21 at noon. Face South. Where should the noon Sun be found with respect to the celestial equator? (ANS: ABOVE THE CELESTIAL EQUATOR) Why should this make sense? (ANS: THE SUN IS DIRECTLY ABOVE THE TROPIC OF CANCER ON THE SUMMER SOLSTICE)

30. Lay your S.P.L. on the desk and place a small piece of paper on the disk just above the ecliptic where it crosses your celestial meridian. Move the disk to the left until the piece of paper meets the horizon. In what direction will the Sun rise on June 21? (ANS: IN THE NORTHEAST) Move the disk to the right until the piece of paper meets the horizon. In what direction will the Sun set on March 21? (ANS: IN THE NORTHWEST) This is the same as which line in diagrams B and C of part 1? (ANS: T)

31. Dial September 23 at noon. Face South. Where should the noon Sun be found with respect to the celestial equator? (ANS: ON THE CELESTIAL EQUATOR) Why should this make sense? (ANS: THE SUN IS DIRECTLY ABOVE THE EQUATOR ON THE FALL (AUTUMNAL) EQUINOX)

32. Lay your S.P.L. on the desk and place a small piece of paper on the disk just above the ecliptic where it crosses your celestial meridian. Move the disk to the left until the piece of paper meets the horizon. In what direction will the Sun rise on September 23? (ANS: DIRECTLY EAST) Move the disk to the right until the piece of paper meets the horizon. In what direction will the Sun set on September 23? (ANS: DIRECTLY WEST) This is the same as which line in diagrams B and C of part 1? (ANS: Q)

33. Dial December 21 at noon. Face South. Where should the noon Sun be found with respect to the celestial equator? (ANS: BELOW THE CELESTIAL EQUATOR) Why should this make sense? (ANS: THE SUN IS DIRECTLY ABOVE THE TROPIC OF CAPRICORN ON THE WINTER SOLSTICE)

34. Lay your S.P.L. on the desk and place a small piece of paper on the disk just above the ecliptic where it crosses your celestial meridian. Move the disk to the left until the piece of paper meets the horizon. In what direction will the Sun rise on December 21? (ANS: IN THE SOUTHEAST) Move the disk to the right until the piece of paper meets the horizon. In what direction will the Sun set on December 21? (ANS: IN THE SOUTHWEST) This is the same as which line in diagrams B and C of part 1? (ANS: R)
PART 3: Look at DIAGRAM D. Think about what you just did with your S.P.L. and how the ecliptic line moved with respect to the celestial equator. DIAGRAM D shows the same motion of the Sun in different ways. Notice how the Sun is over the equator on the spring and fall equinoxes. See how it climbs above the equator at the summer solstice and falls below the equator on the winter solstice? This is the same information you found in questions 11 - 18.

Use DIAGRAM D to answer questions 19 through 00. The diagram represents the location of the Sun relative to the Tropics of Cancer and Capricorn, as well as the Equator.

DIAGRAM D (Angles are not accurate)

35. What apparent direction is the Sun traveling after December 21? (ANS: TOWARD THE NORTH)

36. What apparent direction is the Sun traveling after June 21? (ANS: TOWARD THE SOUTH)

37. Is the Sun above or below the Equator from March 22 to September 22? (ANS: ABOVE)

38. Is the Sun above or below the Equator from September 24 to March 21? (ANS: BELOW)

Imagine yourself standing at the equator. Direction choices include North, South and Zenith.

39. In which general direction would you look to see the noon Sun on March 21? (ANS: ZENITH)

40. In which general direction would you look to see the noon Sun on June 21? (ANS: NORTH)

41. In which general direction would you look to see the noon Sun on September 23? (ANS: ZENITH)

42. In which general direction would you look to see the noon Sun on December 21? (ANS: SOUTH)
Imagine yourself standing at the Tropic of Cancer. Direction choices include North, South and Zenith.

43. In which general direction would you look to see the noon Sun on March 21? (ANS: SOUTH)

44. In which general direction would you look to see the noon Sun on June 21? (ANS: ZENITH)

45. In which general direction would you look to see the noon Sun on September 23? (ANS: SOUTH)

46. In which general direction would you look to see the noon Sun on December 21? (ANS: SOUTH)

47. In which direction will you NEVER look to see the noon Sun from the Tropic of Cancer? (ANS: NORTH) Why?
   (ANS: THE TILT OF THE EARTH IS ONLY 23°. IN ORDER FOR THE SUN TO APPEAR NORTH PAST YOUR ZENITH AT THE TROPIC OF CANCER, THE TILT WOULD HAVE TO BE GREATER)

Imagine yourself standing at the Tropic of Capricorn. Direction choices include North, South and Zenith.

48. In which general direction would you look to see the noon Sun on March 21? (ANS: NORTH)

49. In which general direction would you look to see the noon Sun on June 21? (ANS: NORTH)

50. In which general direction would you look to see the noon Sun on September 23? (ANS: NORTH)

51. In which general direction would you look to see the noon Sun on December 21? (ANS: ZENITH)

52. In which direction will you NEVER look to see the noon Sun from the Tropic of Capricorn? (ANS: SOUTH) Why?
   (ANS: THE TILT OF THE EARTH IS ONLY 23°. IN ORDER FOR THE SUN TO APPEAR NORTH PAST YOUR ZENITH AT THE TROPIC OF CAPRICORN, THE TILT WOULD HAVE TO BE GREATER)
**ACTIVITY 16: Why is it Hot in the Summer and Cold in The Winter?**

**OBJECTIVE**

The student should be able to explain and demonstrate with flashlight why it’s warm in the summer and cold in the winter. Showing how the Sun angle changes with the seasons does this.

**MATERIALS:**

1. A piece of white poster board (approximate size or bigger 10” x 10”).
2. A flashlight.

**PROCEDURE/INTERPRETATION**

The demonstration should follow the diagram below. The tilts are exaggerated since we are using a flat surface rather than a curved surface. **NOTE:** How the flashlight changes position from summer to winter relative to the poster board.

1. Measure the distance between A & B. Measure the distance between C & D. Which one has the greatest distance?  **ANS: CD**

2. What did you notice about the circle of sunlight that struck the N. Hemisphere in the summer position compared to the circle of sunlight that struck the N. Hemisphere in the winter position?  **ANS:** During the summer position the light is more direct; in the winter the light is more spread out.

3. Why are summer days so hot and winter days so cold?  **ANS:** The N. Hemisphere is receiving more direct sunlight during the summer. During the winter, because the Sun is so low, the light from the Sun is more spread out over the N. Hemisphere; thus, it’s not nearly as intense as the summer Sun.

4. Does the changing distance from the Sun have anything to do with the fact that it is hot in our summer and cold in our winter?  **ANS:** Absolutely not

5. Does the changing distance from the Sun have anything to do with the fact that the length of summer is two days longer than the length of winter.  **ANS:** Absolutely yes

6. Why is the Sun high in our summer day sky and low in our winter day sky? Why do we have seasons?  **ANS:** The Earth is tilted and it goes around (revolution, orbit) the Sun.
ACTIVITY 17: Land of the Midnight Sun

Objective: Student will use the S.P.L. to determine positions of the sun and circumpolar constellations during different seasons within the Arctic Circle.

Materials: Toothpicks, S.P.L.

Procedure / Interpretations:
You will need the diagram at the right and two toothpicks. Label one toothpick CE for "Celestial Equator" and the other P for "Polaris". These two toothpicks need to be held at a right angle at all times. It may help to tape them or glue them together.

1. In the Northern Hemisphere, the altitude of Polaris is the same as the latitude from which it is seen. To represent our latitude (40° N) you will need to tilt the "Polaris" toothpick to what altitude? (ANS: 40°)

2. With the "Polaris" toothpick aligned to our latitude, at what altitude is the "Celestial Equator" toothpick pointing? (ANS: 50°)

3. At this latitude (40° N), all stars within an area 40° to either side of your Polaris toothpick are considered circumpolar stars. Circumpolar stars would be seen from as low as the (ANS: THE HORIZON) to as high as 80°.

4. Tilt Polaris to represent being at 50° N. Now where is the Celestial Meridian? (ANS: 40°)

The radius of circumpolars now increases to 50° either side of your Polaris toothpick. Circumpolars would now be seen from as low as the horizon to (ANS: 10° PAST ZENITH)

Are you seeing more or fewer circumpolar stars at this latitude? (ANS: MORE)

5. Continue moving Polaris until you reach 90°N. Where are you if you are at 90°N? (ANS: NORTH POLE)

6. At 90° N latitude, what is the altitude of Polaris? (ANS: 90°) This means to see Polaris in the night sky you need to look (ANS: ZENITH OR STRAIGHT UP)

7. What about the area of circumpolar stars? Now, they range from the horizon to (ANS: HORIZON) So, at the North Pole (ANS: ALL) stars are circumpolar!
8. As you increased in latitude what happened to the altitude of Polaris? (ANS: INCREASED) The altitude of the celestial equator? (ANS: DECREASED) The number of circumpolar stars? (ANS: INCREASED)

9. When you are at 90°N latitude at what altitude is your celestial equator? (ANS: AT 0°) This means the celestial equator is seen along the (ANS: HORIZON).

10. Think about the position of the noon sun along the ecliptic on March 21. The ecliptic is the same as what other position on this date? (ANS: CELESTIAL EQUATOR) So, at the North Pole on March 21, the noon Sun would be seen where? (ANS: ALONG THE HORIZON) and it would be CIRCUMPOLAR! The sun would travel along the horizon for 24 hours!

11. In the Northern Hemisphere, does the sun get higher or lower in the sky from March 21 to June 21? (ANS: HIGHER)

So, from March 21 to June 21 at the North Pole, the sun would be visible for 24 hours each day and seem to spiral (up/down) (ANS: UP) into the sky.

12. Do you have to be at the North Pole to see the Sun at midnight? ANS: No. On June 21, the Sun is directly over which Tropic? (ANS: CANCER) What is the latitude of this Tropic? (see diagram D for a hint) (ANS: 23.5° THEY MAY ROUND TO 23)

13. Math time! Subtract the latitude of the Tropic of Cancer from the latitude of the North Pole. Your answer: (ANS: 66.5° THEY MAY ROUND TO 67) This latitude is known as the (ANS: ARCTIC CIRCLE)

So between March 21 and June 21, everyone between the Arctic Circle and the North Pole will see the Sun spiraling up into the sky and have 24 hours of daylight each day!

14. Extension: You are living within the Arctic Circle. What will the Sun be doing from June 21 to September 23? (ANS: GETTING LOWER IN THE SKY)

What will happen to the Sun from September 24 to December 21? (ANS: IT WILL BE BELOW THE HORIZON. THE SKY WILL GET LIGHT LIKE DAWN, BUT THEY WILL NOT SEE THE SUN)
**ACTIVITY 18:** The Varying Lengths of the Seasons

Objective:
Student will determine the number of days per season to infer the orbital shape of Earth.

**Materials:** Calendar

**PROCEDURE / INTERPRETATIONS:**
1. How many days are there from the Spring Equinox and the Summer Solstice? (ANS: 92)
2. How many days are there from the Summer Solstice and the Fall Equinox? (ANS: 94)
3. How many days are there from the Fall Equinox and the Winter Solstice? (ANS: 90)
4. How many days are there from the Winter Solstice and the Spring Equinox? (ANS: 89)
5. If the earth spends more time in Spring and Summer, the distance it is traveling around the Sun during those seasons must be which, longer or shorter? (ANS: LONGER) This means the Earth is which, farther from or closer to the Sun during those seasons? (ANS: FARTHER FROM)

**INFORMATION:**
The Earth's orbit is elliptical (egg-shaped) which means the Earth's distance from the Sun varies. (See Diagram E). **APHELION** (farthest distance from the Sun) occurs during **summer** on **July 4**, when the Earth's angular rate of motion reaches a minimum of 0°.57'/day.

During the **winter**, the distance between the Earth and the Sun is at a MINIMUM (**PERIHELION**). This means the Earth is moving through a greater angular distance, which results in greater speed. Perihelion occurs on **January 4** with the Earth moving at 1°.01'/day.

**DIAGRAM E**

```
Spring        Winter

Aphelion     Sun     Perihelion

Summer      Fall
```

Most people believe **summer** occurs when the Earth is closest to the Sun; **winter**, when it is farthest from the Sun. **WRONG!** (The change in distance from the Sun, between summer and winter, is only three percent.) Seasons are determined by the length of time the Sun is above the horizon and how high it gets during the day. Long days heat the Earth more than short days. What accounts for the changing daylight hours? A Tilted Earth.

During the Summer in the northern hemisphere the North Pole is tilted toward the Sun. Thus, the northern hemisphere is receiving more direct sunlight. In the southern hemisphere the sun's light is coming in at a lower angle; therefore, the Sun's light is not as direct - it's more spread out making it less intense. For instance on June 21, here in the northern hemisphere, the path of the Sun is very long and the noon altitude is as high as the Sun gets all year. While at the same time in the southern hemisphere just the opposite is occurring. The path of the Sun is the shortest and the altitude of the noon Sun is the lowest for the entire year.
ACTIVITY 19: Differing Lengths of Daylight Hours at the Solstices

Objective:

Students will use the S.P.L. to reinforce the idea of seasons being caused by intensity and length of daylight.

Materials: S.P.L
Small piece of Masking Tape about 4mm by 6mm

PROCEDURE / INTERPRETATIONS:

Dial June 21 at noon on your S.P.L. Face South. Lay your S.P.L on the desk and stick the corner of the masking tape on the rotating wheel at the intersection of the ecliptic and string (celestial meridian). This would be the location of the noon sun for June 21. Now move the wheel to the left until the corner of the tape meets the eastern horizon.

1. What time do you see for June 21? ANS: Approximately 4:30am. This is sunrise time for June 21

2. What direction does the sun appear to rise for June 21? AND: NE

Move the wheel to the right until the same corner of the tape is on the western horizon.

3. What time do you see for June 21? ANS: Approximately 7:30pm. This is the sunset time for June 21

4. What direction did the Sun appear to set for June 21? ANS: NW

5. How many hours of daylight does one have in the middle latitudes of the northern hemisphere on June 21? ANS: 15 hrs

Dial December 21 at noon on your S.P.L. Face South Lay your S.P.L on the desk and stick the corner of the masking tape on the rotating wheel at the intersection of the ecliptic and string (celestial meridian). This would be the location of the noon sun for December 21. Now move the wheel to the left until the corner of the tape meets the eastern horizon.

6. What time do you see for December 21? ANS: Approximately 7:30am This is sunrise time for December 21

7. What direction does the sun appear to rise for December 21? AND: SE

Move the wheel to the right until the same corner of the tape is on the western horizon.

8. What time do you see for December 21? ANS: Approximately 4:30pm This is the sunset time for December 21

9. What direction did the Sun appear to set for June 21? ANS: SW

10. How many hours of daylight does one have in the middle latitudes of the northern hemisphere on June 21? ANS: 9hrs
11. During which solstice did it take the Sun the longest time to cross the sky? (ANS: SUMMER)

12. During which solstice are we tilted directly toward the Sun? (ANS: SUMMER)

13. So, during (summer / winter) (ANS: SUMMER) we in the Northern Hemisphere are receiving more direct sunlight for (more / fewer) (ANS: MORE) hours. No wonder it’s warmer!

14. And, during (summer / winter) (ANS: WINTER) we in the Northern Hemisphere are receiving less direct sunlight for (more / fewer) (ANS: FEWER) hours. No wonder it’s colder!

15. Seasons occur because of the tilt of the Earth. The tilt affects what two things? (ANS: DIRECTNESS OF SUNLIGHT AND LENGTH OF DAY)

16. T/F Distance from the Sun has absolutely nothing to do with the reasons for the seasons. (ANS: TRUE)

17. T/F The length of a season is affected by the Earth’s distance from the Sun. (ANS: TRUE)

18. T/F The earth is closer to the Sun during our (40°N) winter? (ANS: TRUE)

19. What two things produce seasons? ANS: Tilt and Revolution
ACTIVITY 20: Naming the Tropics

Objective:
Student will use the S.P.L. to research the origin of the names Tropic of Cancer and Tropic of Capricorn

Materials: S.P.L.

PROCEDURE/INTERPRETATIONS:

The latitude line marking 23.5°N is called Tropic of Cancer because between four thousand to two thousand years ago the Sun came up in Cancer on June 21.

1. Dial in June 21, at a sunrise time of 5:30 am. We know the Sun on June 21 will come up in the direction of (NE, E, SE) (ANS: NE)

2. Follow an imaginary line from the zenith to the NE and along the horizon you will see the location of the Sun and the zodiac constellation it is located. Name the zodiac constellation. (ANS: GEMINI)

3. Raise the border of the S.P.L. and note the constellation that is left of it on the ecliptic. What is the name of this constellation? (ANS: CANCER)

4. Two thousand years ago Cancer was on the horizon. Gemini has replaced it; therefore, we should now call 23.5°N the Tropic of (ANS: GEMINI)

The latitude line marking 23.5°S is called the Tropic of Capricorn because four thousand to two thousand years ago the Sun came up in Capricorn on December 21.

5. Dial December 21 at a sunrise time of 8 am. We know the Sun on December 21 will come up in the (NE, E, SE) (ANS: SE)

6. Follow an imaginary line from the zenith to the SE. Raise the border of the S.P.L. and you will see a zodiac constellation along the horizon. Which one? (ANS: SAGITTARIUS) As you can see by looking farther east, Capricornus is now below the horizon; however, two thousand years ago it was on the horizon.


8. Why have the zodiac signs (constellations) shifted toward the east during the past two thousand years? (ANS: Precession)
**ACTIVITY 21: Summary: Seasons & the Ecliptic**

**Objective:**
Students will use prior activity knowledge to form an integrated "working picture" of the motions of celestial bodies during the year.

**Materials:** S.P.L.

**PROCEDURE / INTERPRETATIONS:**

**DIAGRAM F**

<table>
<thead>
<tr>
<th>June 21</th>
<th>December 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night Ecliptic</td>
<td>Day Ecliptic (Sun)</td>
</tr>
<tr>
<td>Midnight</td>
<td>Noon</td>
</tr>
<tr>
<td>$-23^\circ$</td>
<td>$+23^\circ$</td>
</tr>
<tr>
<td>Day Ecliptic (Sun)</td>
<td>Night Ecliptic</td>
</tr>
<tr>
<td>Noon</td>
<td>Midnight</td>
</tr>
<tr>
<td>$-23^\circ$</td>
<td>$+23^\circ$</td>
</tr>
</tbody>
</table>

**REMINDER:**

The *ecliptic* represents the path the Sun makes across the sky in the course of a year. We can also say, the ecliptic is an imaginary line connecting the Earth to the Sun, extending through and beyond the Earth to include the *Moon, planets and zodiac constellations*. Therefore, the ecliptic not only represents the position of the noon Sun (intersection of ecliptic and celestial meridian) DURING THE DAY, but it also represents the general location of the planets, zodiac constellations and the Moon DURING THE NIGHT.

On your S.P.L. the ecliptic is represented by the dashed curved line which is the same as to dashed line in **DIAGRAM F**

Use Diagram F and Your S.P.L. to Answer Questions 1 – 23. When using your S.P.L. for NOON or MIDNIGHT interpretations always look at the **intersection of the celestial meridian and ecliptic**.

1. Use diagram F. On June 21, at noon, is the ecliptic (Sun) above or below the equator? (ANS: ABOVE)

2. Verify your answer to question 1 by using your S.P.L. Dial June 21 at noon. Is the ecliptic above or below the equator? (ANS: ABOVE)

3. Look at letter A on the diagram. This part of the ecliptic (Sun) would be directly over what? (ANS: THE TROPIC OF CANCER)

4. Look at letter B on the diagram. This latitude line represents the (ANS: ARCTIC CIRCLE), sometimes called the Land of the (ANS: MIDNIGHT SUN)

5. Use diagram F. On June 21, at midnight, is the ecliptic above or below the equator? (ANS: BELOW)

6. Verify your answer to question 5 by using your S.P.L. Dial June 21 at midnight. Is the ecliptic above or below the equator? (ANS: BELOW)

7. During the summer night sky, will planets and the full Moon be high in our sky or low? (ANS: LOW)
8. Use diagram F. On December 21, at noon, is the ecliptic (Sun) above or below the equator? (ANS: BELOW)

9. Verify your answer for question 8 by using your S.P.L.. Dial December 21 at noon. Is the ecliptic (Sun) above or below the equator? (ANS: BELOW)

10. Look at letter C on the diagram. This part of the ecliptic (Sun) would be directly over what? (ANS: THE TROPIC OF CAPRICORN)

11. Look at letter D on the diagram. This latitude line represents the (ANS: ANTARCTIC CIRCLE), sometimes called the Land of the (ANS: MIDNIGHT SUN)

12. Use diagram F. On December 21, at midnight, is the ecliptic above or below the equator? (ANS: ABOVE)

13. Verify your answer to question 12 by using your S.P.L.. Dial December 21 at midnight. Is the ecliptic above or below the equator? (ANS: ABOVE)

14. During the winter night sky, will planets and the full Moon be high in our sky or low? (ANS: HIGH)

15. Use your S.P.L.. Dial March 21 at noon. Is the ecliptic (Sun) above, on, or below the equator? (A: ON)

16. Use your S.P.L.. Dial March 21 at midnight. Is the ecliptic above, on or below the equator? (ANS: ON)

17. Use your S.P.L.. Dial September 23 at noon. Is the ecliptic (Sun) above, on or below the equator? (ANS: ON)

18. Use your S.P.L.. Dial September 23 at midnight. Is the ecliptic above, on, or below the equator? (A: ON)

19. During the summer, at noon, the Sun will be (high/low) (ANS: HIGH) in the sky. That night the zodiac constellations, planets and full Moon will be (high/low) (ANS: LOW) in the sky.

20. During the winter, at noon, the Sun will be (high/low) (ANS: LOW) in the sky. That night the zodiac constellations, planets, and full Moon will (high/low) (ANS: HIGH) in the sky.

21. T/F The path of the Sun during the summer represents the path of the full Moon during the winter. (ANS: TRUE)

22. T/F The path of the Sun today represents the path of the full Moon six months from now. (ANS: TRUE)

23. T/F On the first day of spring/fall the path of the Sun at noon represents the path of the full Moon that night. (ANS: TRUE)