To Everything ... Turn, Turn, Turn ... There is a Season... Turn, Turn, Turn: What’s the reason for the seasons?

Objectives

- Using their own body movements, the students will study the relationship between time and the astronomical motions of the Earth (rotation on its axis, and its orbit around the Sun).
- Students will gain an understanding of how and why what we see in the sky changes at various times of the day and year.
- Students will be able to describe how and why the tilt of the Earth’s axis (points towards the North Star, Polaris) affects the orientation of the Earth’s hemispheres toward or away from the Sun at different times of the year.
- Using the tilt of the Earth’s axis at $23\frac{1}{2}^\circ$ towards Polaris, students will be able to demonstrate why the Sun is higher in the sky in the summer and lower in the sky in the winter and why this results in the various seasons.
- To be able to identify the path or ecliptic followed by the Sun as it passes through the Zodiac Constellations
- To apply kinesthetic reasons for the seasons to the use of celestial spheres or globes.
- To examine empirical data to determine possible reasons for the seasons.

Suggested Grade Level

Seventh - Twelfth Kinesthetic activities
Eleventh - Twelfth Optimum to use all activities included

Subject Areas

Physical Science
Astronomy

Timeline

Five to Seven 1-hour class periods for the main activities

Background

This lesson explores and expands upon the concepts about the reason for the seasons. The Exploration activities will be taught kinesthetically. During the Extension activities, student groups will examine laboratory data to support or refute the reason for the seasons. These additional activities will be taught following a kinesthetic study or review of basic concepts such as:

- An understanding of a proper size scale and distance scale for objects within our Solar System and the nearest star (especially the Earth and the Sun);
- The daily motions of the Sun in the sky;
- The location of Earth’s poles and equator;
- Familiarity with Earth’s systems of latitude and longitude;
- Rotation of the earth = 1 day in a counterclockwise fashion;
Correct use of the “E” and “W” cards;  
Orbiting the Sun = 365 days;  
Knowledge of terms such as equinox and solstice and their calendar dates;  
Knowledge of constellations as fixed patterns in the night sky;  
Knowledge of the definition of a complete circle to be 360 degrees;  
The ability to approximate 45º, 90º, and 180º angles;  
For high school astronomy students, a working knowledge of the celestial coordinate systems and vocabulary such as altitude and azimuth, right ascension and declination, would help with some of the extension activities.

The next investigations (not included here) would use the concepts from this investigation and Miller’s Planispheres (40ºN Latitude) to verify the motion of the celestial objects and would include how to kinesthetically and visually determine the current positions of Mercury, Venus, Earth, Mars, Jupiter and Saturn.

Materials
Location/Setting: An indoor or outdoor space large enough for your students to form a circle with arms outstretched to their sides. For a class of 25-30 students the space would be equivalent to half a basketball court. This lesson requires the participation of a minimum of eight students.

Props for Kinesthetic Activities (Morrow and Zawaski, 2004):
Each class requires:
- A sphere the size of a large grapefruit to represent a scale model of the Sun
- The tip of a ball point pen or pencil to represent a scale model of the Earth
- An object to represent the Sun at the center of the circle (e.g., a Helium-filled balloon)
- 12 Zodiac Signs and masking tape to attach them to 12 chairs
- A sphere to show the distribution of continents on the Planet Earth (globe or inflatable Earth)
- Signs for each of the 4 Seasons with dates of equinoxes and solstices
- Flashlight or light source that produces a bright beam of light
- A red laser light (optional)

Each student needs:
- A pair of “E” and “W” cards (laminate if possible)
- Popsicle sticks for each card
- Tape to attach them
- One Action figure of their choice
- Personal Student Science Notebook or Science Journal

For the extension lab activities, each lab group of students will need:
- One Celestial Globe
- One metric ruler
- 1-stopwatch
- 1-ring stand
- 1-light assembly
- 3-thermometers
- 3- triangular wooden blocks
• 1-200 watt light bulb
• 1-ruler
• masking tape
• Data retrieved from Astronomical Applications Dept. U.S. Naval Observatory Washington, DC for Norman, Oklahoma (W 97 26, N35 13) 
  http://aa.usno.navy.mil/
• Graph paper
• Overhead projector sheets
• Vis-à-vis markers or colored pencils and/or markers

Safety –
1. Check for obstacles or uneven surfaces in and around the Kinesthetic Circle.
2. If a laser penlight is used to demonstrate the direct rays of the Sun, safety procedures should be observed. It should never be shone in anyone’s eyes and should always be directed at the Globe in use.
3. Glass hazards exist with the use of thermometers. Demonstrate correct use. Show students how to store them so they do not roll off the lab tables.

Lesson
Pre-lesson Assessment will take place at the end of the previous lesson (See addendum section).
Day 1 –
1. Vocabulary
   Axis – A straight line about which a body or geometric object rotates or may be conceived to rotate.
   Polaris – A star of the second magnitude, at the end of the handle of the Little Dipper and almost at the north celestial pole.
   Ecliptic - The intersection plane of the earth's orbit with the celestial sphere, along which the sun appears to move as viewed from the earth.
   Zodiac - A band of the celestial sphere extending about 8° to either side of the ecliptic that represents the path of the principal planets, the moon, and the sun.
   Celestial spheres - the apparent surface of the imaginary sphere on which celestial bodies appear to be projected.
   Equinoxes – Either of two points on the celestial sphere at which the ecliptic intersects the celestial equator.
   Solstices – Either of two times of the year when the sun is at its greatest distance from the celestial equator.
   Alpha Centauri – A multiple star in Centaurus whose three components represent the brightest object in the constellation, 4.4 light-years from Earth.
   Milky Way Galaxy – the galaxy containing the solar system: consists of millions of stars that can be seen as a diffuse band of light stretching across the night sky
   Hemisphere – Either the northern or southern half of the earth as divided by the equator or the eastern or western half as divided by a meridian.
   Equator – The imaginary great circle around the earth's surface, equidistant from the poles and perpendicular to the earth's axis of rotation. It divides the earth into the Northern Hemisphere and the Southern Hemisphere.
   Meridian - The line that runs north-south, midway between your east and west.
Orbit – Is the path in space of one body around another. Orbits are usually elliptical in shape, although the orbits of planets scarcely depart from circles. Rotation - The act or process of turning around a center or an axis: the axial rotation of the earth. 
Zodiac – Is a region of the night sky that corresponds to the Sun’s pathway, containing 12 zodiacal constellations.

2. Proceed to your previously selected area and form a large circle by having students extend their arms. In advance, have the students set up 12 chairs and masking tape. Tape the Zodiac constellation pictures to each chair (one per chair). Place the chairs in the correct order of the Zodiac constellations before the students begin. Have the students arrange themselves in a Kinesthetic Circle within the Zodiac Circle.

3. Begin the class by reviewing student understandings of kinesthetic astronomy concepts such as the proper scale and distance of the Sun and the earth; rotation of the Earth (and day length), the orbit of the Earth around the Sun (and length of year). The teacher should ask a series of leading questions to assess the students understanding of their previous kinesthetic lessons. Ask for volunteers and/or assign groups of students to demonstrate the background concepts before proceeding with the lesson on the seasons. Gently question and guide them to correct interpretations and correct misconceptions. (15 minutes)

4. Guide the class through the Kinesthetic Astronomy Sky Time Lessons on the seasons. To begin to understand the reasons for the seasons, have students model the tilt of the Earth towards Polaris, the North Star, at 23.5º. All will tilt in the same direction. Some will be leaning forward from the waist and aimed at the Sun while others will be bending backwards and leaning away from the Sun. Some will be bending sideways towards the Sun. The discussion guided by the teacher will ask the students to predict which positions the Northern Hemisphere will be in at the winter and summer solstices. The questions will be repeated for the Southern Hemisphere to determine that each hemisphere has opposite seasons. Provide appropriate signs for each solstice.

5. Next the teacher will ask the students to compare the differences between winter and summer and have them offer their own reasons as to why it is colder in the winter and hotter in the summer. The students should use their scale model for distance to determine if the Earth is significantly closer or farther from the Sun. The teacher must guide students to the idea that the changes in the Earth’s seasons cannot be due to changes in the distances from the Sun.

6. The teacher should ask the students for reasons for the seasons if distance is not a factor. Responses can be recorded in their student notebooks or journals.

7. Remind them that they will need to observe the Night Sky and record any changes they observed.

Day 2 –
1. Begin the class by reviewing yesterday’s activities and questions on their Night Sky observations.
2. Within the classroom, resume the Kinesthetic Circle with students tilted correctly towards Polaris. Students should be lead through a series of questions directed
at explaining why leaning towards the Sun causes the warmth of summer. Relate ideas to height of the Sun in the sky, long or short day length, how day length would change the temperature of the Earth’s surface, what times of day usually produces the hottest/coolest temperatures.

3. Discuss when the Sun’s rays are more direct or indirect. Demonstrate indoors with a flashlight if necessary. Sometimes a red laser penlight can represent the sunlight and directed on a tilted model of the Earth from different locations around the room. The students can quickly observe that the most direct rays hit the Earth tilted towards the Sun at the Summer Solstice and the more indirect ones strike the Earth at the Winter Solstice. Review the differences between the Northern and the Southern Hemispheres.

4. Reform the Kinesthetic Circle have the students examine the students bending sideways. Relate this to the reasons for the Spring and Fall Equinoxes. Ask the students to provide the appropriate dates. Students should predict their locations in the Circle. Resolve any discrepancies that exist. Assign appropriate sign for each equinox.

5. Next students should move to the area of the Circle for their birthdays AT NOON with their “E” and “W” signs. Lead them through a series of questions that makes them examine which Zodiac Constellations are in the sky at midnight on their birthday. Have them return to the NOON positions and point out their personal Zodiac constellation. Explain the meaning behind their Sun Sign. This new observation usually disequilibrates or surprises students because they expect their Zodiac Sign to be in the night sky the night of their birthday.

6. Question students as to whether or not the tilt of the Earth has changed with the various seasons. Have any students who can maintain the tilt correctly kinesthetically demonstrate their explanation.

7. Remind students to observe the Night Sky and note any changes.

Day 3 –

1. Begin the class by reviewing yesterday’s activities and questions about the Night Sky.

2. Students will work in groups of three to four students. The students will apply their kinesthetic understanding of the reasons for the seasons to a 3-D model of the celestial sphere. During the lab the teacher should circulate and ask leading questions to help them relate what they did kinesthetically to the arrangement and organization of the celestial sphere. The sphere will make them apply their knowledge and practice the concepts to which they have been introduced. The teacher should lead a discussion which addresses their understandings and the common misconceptions they have. In their science notebooks, have the students summarize how this model depicts what they acted out in their kinesthetic activities. Have them identify what they liked about their kinesthetic activities and the model of the celestial sphere. Reflect upon which activities helped them to better understand the concepts? In their journals have them record their current understandings and any questions they still may have.

N.B. If you wish to make your own celestial spheres, Project Star (2001) provides a modeling activity in Chapter 3.

3. Remind them to observe the Night Sky and note any changes.
Day 4 –
1. Begin by reviewing yesterday’s modeling activities and discuss any observations about the Night Sky. Review the questions they wrote from Day 3.
2. Provide pre-lab instructions and review safety and proper use and care of thermometers. Introduce the problem that we observed how direct and indirect sunlight affected the earth to cause different seasons. We will attempt to see if these different angles will cause different temperatures. Allow students to make their own predictions, up their own labs, and record their data.
3. Discuss what the data show. How can these results be interpreted?
4. Discuss how the results provide evidence to allow us to accept or reject the angle of insolation as evidence for seasonal temperature differences. Have each lab group present their own conclusions to the class (posterboard or overhead projector sheets).
5. Allow time to clean up and return supplies.

Day 5 –
1. Begin by reviewing yesterday’s experimental results. Finish resolving any unanswered questions raised by the students.
2. Have the students examine data from the Solar and Heliospheric Observatory regarding how altitude and azimuth change at the solstices and equinoxes. The data provided will be useful to anyone within the 30 - 40° N latitude. Have the students observe any trends and then graph their data using a multiple line graph.
3. What do the data mean? Discuss how these data provide evidence to allow us to accept or reject additional reasons for the seasons.

Day 6 –
1. Begin by reviewing yesterday’s activities and conclusions. Answer any additional questions.
2. If time-permits, an open-ended inquiry is provided in which students predict the variables which might affect the angle of insolation at a certain spot on the earth’s surface. Students can choose a variable, design an experiment, carry it out, and report back to their classmates via posterboard, overhead sheets, etc.

Extensions
1. To have students apply their knowledge of the seasons to a 3-D model of the celestial sphere
2. To have students relate the angle of insolation to the temperature of a system
3. To have students examine solar altitude and azimuth data at the various seasons
4. To have students conduct an open-ended inquiry lab where they predict the variables that might affect the angle of insolation at a particular spot on the earth’s surface and choose one variable and design an experiment to test and report on that variable.
• **Night Sky Observations**
Throughout this investigation, have students observe the motion of the sun during the day and the stars at night at different times (e.g., early evening and late evening) and report their observations. Discuss as time and weather permits.

Are they always in the same place or do they move? (They appear to move.)
Why do the stars appear to rise and set? (Have students demonstrate Earth’s rotation kinesthetically as to why the stars rise and set.)
Why does the Sun appear to rise and set? (Have students demonstrate Earth’s rotation kinesthetically as to why the Sun rises and sets.)

**Evaluation-Assessment**

- Students did using their own body movements, the students will study the relationship between time and the astronomical motions of the Earth (rotation on its axis, and its orbit around the Sun).
- Students did gain an understanding of how and why what we see in the sky changes at various times of the day and year.
- Students did be able to describe how and why the tilt of the Earth’s axis (points towards the North Star, Polaris) affects the orientation of the Earth’s hemispheres toward or away from the Sun at different times of the year.
- Students did using the tilt of the Earth’s axis at 23½° towards Polaris, students will be able to demonstrate why the Sun is higher in the sky in the summer and lower in the sky in the winter and why this results in the various seasons.
- Students were able to identify the path or ecliptic followed by the Sun as it passes through the Zodiac Constellations
- Students were able to apply kinesthetic reasons for the seasons to the use of celestial spheres or globes.
- Students did examine empirical data to determine possible reasons for the seasons.
- Students did complete a Pre-Assessment Questionnaire.
- Each day the students will be asked to reflect upon a question regarding the reason for the seasons. Their responses will be entered in student science notebooks/journals which will be reviewed as often as possible to assess student understanding and to identify which strategies help them learn the material.
- Groups of students will be informally assessed throughout these investigations as to how they use kinesthetic strategies to offer explanations for the questions throughout each class.
- Students did complete the following worksheets from the Kinesthetic Astronomy program (Morrow and Zawaski, 2004) either at the end of each class or for homework.
  - “Kinesthetic Seasons” – Student Worksheet (**ST11**)
  - “Reasons-for-Seasons” Concept Map Activity (**ST12-ST13**)
  - “Reasons-for-Seasons” Fill-in-the-blank (**ST14-15**)
  - “What does it mean to be a Leo? Different Stars for Different Seasons” (**ST 16-18**)
- Students did also be assessed as to how they complete the lab worksheets which accompany the addendum activities.
• Students did complete the Anticipation Guide to help them review for an in class exam based upon the Pre-Assessment Questionnaire.

Resources


Addendum #1

What’s Your Sign?

The celestial globe shows all the constellations, the brighter stars, Milky Way, the Messier objects, and other features of the celestial sphere. It is shown from the "outside”, as the earth is inside the celestial sphere. This means that when we look at the sphere, the constellations appear to be reversed left for right from the way we actually see them in the night sky. Fortunately adapting for this is easy. Directions on the globe are the same as on the world globe as shown at right. However, since the earth rotates from west to east, the celestial globe rotates in the opposite direction, from east to west. The stars whose positions are fixed on the sphere, rise in the east and set in the west, as do the sun and moon. The path of the sun is indicated on the globe by a series of hash marks near the celestial equator (the extension of the earth’s equator). This apparent path of the sun is called the **ecliptic**.

**Materials:**
1- celestial globe  
1- ruler

**Procedure:**
1. Find the ecliptic on the celestial sphere.
2. What observations can you make about the ecliptic?

3. Find the right ascension and declination for the following positions of the sun.

<table>
<thead>
<tr>
<th>Sun’s Position</th>
<th>Right Ascension</th>
<th>Declination</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest Point from Celestial Equator</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Lowest Point from the Celestial Equator</td>
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<tr>
<td>Crosses the Celestial Equator</td>
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<td></td>
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<tr>
<td>Crosses the Celestial Equator</td>
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<td></td>
</tr>
</tbody>
</table>

4. What is unique about each of these dates listed in Table 1?
5. List the constellations that are found along the ecliptic:

<table>
<thead>
<tr>
<th>Constellations found along the Ecliptic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

6. What is the name for this group of constellations? ____________________________

7. Find your sun sign based upon your knowledge of astrology:
   Sun Sign: ____________________________

8. During what approximate range of dates, according to the globe, is the sun actually in your sign?
   Range: From ____________________________ (specify date)
   to ____________________________ (specify date)
   = ___________ days

9. List your birthday: ____________________________

10. Is your birthday within this range of dates? ________________ Why or why not?

11. What explanation do you think astrologers give for using sun signs that do not coincide with the actual sign that the sun is in when a person is born?

______________________________________________________________________
______________________________________________________________________

PART 2:

12. The celestial globe may be used to locate the constellations in the sky at any date and time. Find the dates labeled along the ecliptic.

13. Align the sun directly in front of today’s date.

14. Turn the earth so that the sun is also over your state.
   With the sun in this position, what time is it in your state?

15. Slowly turn the sphere clockwise 90 degrees (keep North America facing you).
   **Realize when you do this that it is actually the earth rotating on its axis counterclockwise (west to east).**

15. Complete Table 2. **NOTE:** While completing Tables 2 through 4, understand that these observations are from your position in your home state.

<table>
<thead>
<tr>
<th>Today’s Date Time of Day</th>
<th>General</th>
<th>Constellation Position</th>
<th>Constellation Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rising</td>
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<tr>
<td></td>
<td></td>
<td>Overhead</td>
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<tr>
<td></td>
<td></td>
<td>Setting</td>
<td></td>
</tr>
</tbody>
</table>
17. Now turn the celestial sphere another 90 degrees clockwise (sun is opposite you). How much time has passed? __________
Complete Table 3.

<table>
<thead>
<tr>
<th>Date</th>
<th>General Time of Day</th>
<th>Constellation Position</th>
<th>Constellation Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rising</td>
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<td></td>
<td>Setting</td>
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</tr>
</tbody>
</table>

18. Now turn the celestial sphere another 90 degrees clockwise. How much time has passed? __________
Complete Table 4.

<table>
<thead>
<tr>
<th>Date</th>
<th>General Time of Day</th>
<th>Constellation Position</th>
<th>Constellation Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Rising</td>
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<td>Setting</td>
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</tbody>
</table>

19. What observations can you make about the constellations in the sky at sunset compared to those in the sky at sunrise?

20. How does this model provide evidence to accept or reject our kinesthetic model of the seasons?
Addendum #2

Exploration: Sunny Days are Here Again!

Problem: How does the angle at which sunlight strikes the earth affect the temperature on earth?

Materials:
- 1-stopwatch
- 1-ring stand
- 1-light assembly
- 3-thermometers
- 3-triangular wooden blocks
- 1-light bulb
- 1-ruler
- masking tape

Procedure:
1. Using the masking tape, attach one thermometer to the 30° angle of one block.
2. Attach the second thermometer to the 60° angle of the second block.
3. Attach the third thermometer to the 90° angle of the third block.
4. Attach the light assembly to the ring stand.
5. Position the blocks, with the thermometers attached so that the bulb of each thermometer is 10 cm from the light source.
6. Record the initial temperature of each thermometer on the data table.
7. Switch on the light source.
8. Measure the temperature of each thermometer every minute for ten minutes.
9. Record the temperatures in the data table in your notebook (see example next page)
10. After ten minutes, turn off light source. (CAUTION: Area of table under light EXTREMELY HOT!)

Title:
____________________________________________________________________________

<table>
<thead>
<tr>
<th>Angle (°)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
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<td>60</td>
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<td>90</td>
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</tr>
</tbody>
</table>
11. Graph your data using a multiple line graph.

Title:
Conceptual Invention:

1. How should the light rays from the sun hit the Earth to have the greatest increase in temperature? Smallest increase in temperature?

2. Describe the pattern(s) seen in your graph.

3. What is the angle of insolation?

4. Create and label a diagram that shows the changes in the angle of insolation of the sun’s rays on the Earth.

5. What impact does the angle of insolation of the sun’s rays have on the Earth?

6. How does this experiment provide evidence to accept or reject our kinesthetic astronomical model of an earth year and why we have seasons?
Addendum #3

Expansion A: Sunny Days are here again!

Problem: How does altitude and azimuth change at the solstices and the equinoxes?

You are a part of NASA's Solar and Heliospheric Observation team (SOHO). You and your team have been assigned to compare the path of the sun's yearlong path from sunrise to sunset. Since this is almost impossible to do in one class period, the data has been generously collected for you by your counterparts at the US Naval Observatory.

Your task is to graph the data sets for the following dates and examine your results:

- December 21
- June 21
- Closest month to today's date (either March or September)

1. Altitude will be on your y-axis and azimuth will be on your x-axis (remember, azimuth is the same as the compass direction, i.e. east = 90° and west = 270°).
2. To find your interval, divide your data range (high-low) by the number of lines on the graph.
3. Begin your plotting with the first data set under the horizon (time does not matter in this exercise).
4. Draw a best fit line for each month.
5. Ensure that you have a key to indicate each month (use different colors, patterns for data points, etc.)
6. Draw and label the following:
   - horizon
   - east, west, south, and north on the azimuth
   - meridian (extend this line from the horizon to the highest point plotted on the graph)

What do you see?

1. For the Sun, what is the highest altitude, during what month? __________
   What season is this in the Northern Hemisphere? _______________
2. For the Sun, what is the lowest altitude, during what month? __________
   What season is this in the Northern Hemisphere? _______________
3. During which month does the Sun remain above the horizon for the longest period? ______
4. During which month does the Sun remain above the horizon for the shortest period? ______
5. What time of day does the sun reach its highest altitude? ______________
6. Given that the sun travels 15 degrees per hour, how much time passes between sunrise and sunset for each month plotted?
7. How does the time of year affect how we see the path of the sun? HINT: Use the above questions to help you.
8. How do these data provide evidence to accept or reject our kinesthetic astronomical model of an earth year and why we have seasons?
Altitude and Azimuth of the Sun


<table>
<thead>
<tr>
<th>Date</th>
<th>Central Standard Time</th>
<th>Altitude</th>
<th>Azimuth (E of N)</th>
<th>Altitude</th>
<th>Azimuth (E of N)</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06:00</td>
<td>-7.5</td>
<td>84.5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>07:00</td>
<td>4.9</td>
<td>93.2</td>
<td></td>
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</tr>
<tr>
<td>08:00</td>
<td>16.9</td>
<td>102.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>09:00</td>
<td>28.6</td>
<td>112.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>39.4</td>
<td>125.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td>48.3</td>
<td>141.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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Astronomy                                             Sunny Days are Here Again! 16
Addendum #4 or use an appropriate reading from the textbook of your choice.

**Expansion B: To Every Time There Is A Season**

The seasonal temperature depends on the amount of heat received from the Sun in a given time. To hold the temperature constant, there must be a balance between the amount of heat gained and the amount radiated to space. If more heat is received than is lost, your location gets warmer; if more heat is lost than gained, your location gets cooler. What causes the amount of energy reaching a given location during the day to change throughout the year?

Two popular theories are often stated to explain the temperature differences of the seasons: 1) the different distances the Earth is from the Sun in its elliptical orbit (at perihelion the Earth is 147.1 million kilometers from the Sun and at aphelion the Earth is 152.1 million kilometers from the Sun); and 2) the tilt of the Earth's axis with respect to its orbital plane. If the first theory were true, then both the north and south hemispheres should experience the same seasons at the same time. They do not.

A popular variation of the distance theory says that the part of the Earth tilted toward the Sun should be hotter than the part tilted away from the Sun because of the differences in distances. If you continue along with this line of reasoning, then you conclude that the night side of the Earth is colder than the daylight side because the night side is farther away from the Sun. This ignores the more straightforward reason that the night side is directed opposite the Sun, so the Sun's energy does not directly reach it.

Even though the distance model (in any variation) is incorrect, it is still a `good" scientific theory in that it makes testable predictions of how the temperature should change throughout the year and by how much.
The Earth's rotation axis is tilted by 23.5° with respect to the ecliptic and is always pointed to the celestial poles as the Earth moves around the Sun. Sometimes the northern hemisphere is tilted away from the Sun and the Sun's rays hit the northern hemisphere at a shallow angle. This is winter in the northern hemisphere (summer in the southern hemisphere). Sometimes the northern hemisphere is tilted toward the Sun and the Sun's rays hit the northern hemisphere at a sharp angle. This is summer in the northern hemisphere (winter in the southern hemisphere). The rotation axis itself wobbles (precesses) with a period of about 26,000 years, so the celestial pole directions slowly change. However, from year-to-year, this effect is too small to notice without sensitive equipment.

The tilt theory correctly explains that the seasons are caused due to the Earth's tilted rotational axis. The north hemisphere will be pointed toward the Sun and will experience summer while the south hemisphere will be pointed away from the Sun and will experience winter. During the summer the sunlight strikes the ground more directly (closer to perpendicular), concentrating the Sun's energy. This concentrated energy is able to heat the surface more quickly than during the wintertime when the Sun's rays hit the ground at more glancing angles, spreading out the energy.

Also, during the summer the Sun is above the horizon for a longer time so its energy has more time to heat things up than during the winter.
The rotational axes of most of the other planets of the solar system are also tilted with respect to their orbital planes so they undergo seasonal changes in their temperatures too. The planets Mercury, Jupiter, and Venus have very small tilts (3° or less) so the varying distance they are from the Sun may play more of a role in any seasonal temperature variations. However, of these three, only Mercury has significant differences between perihelion and aphelion. Its extremely thin atmosphere is not able to retain any of the Sun's energy. Jupiter's and Venus' orbits are very nearly circular and their atmospheres are very thick, so their temperature variations are near zero.

Mars, Saturn, and Neptune have tilts that are similar to the Earth's, but Saturn and Neptune have near zero temperature variation because of their very thick atmospheres and nearly circular orbits. Mars has large temperature changes because of its very thin atmosphere and its more eccentric orbit places its Southern Hemisphere closest to the Sun during its summer and farthest from the Sun during its winter. Mars' Northern Hemisphere has milder seasonal variation than its Southern Hemisphere because of this arrangement. Since planets move slowest in their orbits when they are furthest from the Sun, Mars' Southern Hemisphere has short, hot summers and long, cold winters.

Uranus' seasons should be the most unusual because it orbits the Sun on its side---its axis is tilted by 98 degrees! For half of the Uranian year, one hemisphere is in sunlight and the other is in the dark. For the other half of the Uranian year, the situation is reversed. The thick atmosphere of Uranus distributes the solar energy from one hemisphere to the other effectively, so the seasonal temperature changes are near zero. Pluto's axis is also tilted by a large amount (122.5 degrees), its orbit is the most elliptical of the planets, and it has an extremely thin atmosphere. But it is always so far from the Sun that it is perpetually in deep freeze (only 50 degrees above absolute zero!).
Review Questions

1. What causes the temperature differences between the seasons? How so?

2. If you shine a flashlight on a flat tabletop, which gives you a smaller concentrated beam: one directed perpendicular to the tabletop or one directed parallel to the tabletop? Which one produces the longer shadow of a pencil on the tabletop?

3. How would the fact that the Sun's angular size is largest around January 4 contradict the popular theory that the Earth's distance from the Sun in its elliptical orbit causes the seasons?
Addendum #5

Expansion C: Open Ended Inquiry

In the Exploration and Expansion activities you saw how the angle of insolation affected the temperature on the Earth.

Problem: What variables may influence the rate of warming of a particular spot on the Earth’s surface?

Predictions: (Record ideas from class discussion)

Choose one variable and write it as a hypothesis.

Hypothesis:

Design an experiment to test your variable.
Materials: (List anything needed for someone else to reproduce your experiment and get the same results.)

Procedure: (List a step-by-step explanation as to how you proceeded.)

Data: (Design appropriate charts and graphs to display your data)

Data Analysis: (Write a paragraph where you discuss your results.)

Conclusion
(NPS Astronomy Curriculum Development)
#1 - High School Astronomy: Celestial Globe Activity - What’s Your Sign?
#2 – How does the angle at which sunlight strikes the earth affect the temperature on earth?
#3 - How does altitude and azimuth change at the solstices and the equinoxes?
#4 – “To Everything There is a Season” Reading and Questions
#5 – Open-Ended Inquiry: What variables may influence the rate of warming of a particular spot on the earth’s surface?
#6 – Pre-Assessment Questionnaire
#7 – Anticipation Guide for Seasons & Kinesthetic Astronomy