Why do we have seasons?

Names and group picture

Objective: When you have completed this lab you should be able to show how the tilt of Earth’s axis and Earth’s revolution around the sun cause seasonal variations in…

- Temperature
- Day length
- Height of the noonday sun

Part 1: Eliciting **your** understanding of the causes of the seasons

We spent the last lab analyzing why the equator is warmer than the poles. But, as you well know, our weather is not the same all year round. It is warmer in the summer than in the winter. The purpose of this activity is for you to lay out what you know (or at least what you think) about the causes of the seasons and then refine that *model* in light of further evidence and reflection.

Materials: Glowing light bulb (representing the sun)
Polystyrene ball with a stick through the center of it (the stick represents Earth's axis of rotation)

Activity: Within your group, take turns expressing your ideas about the causes of the seasons. Use the lamp and small globe as props for your explanations. Don't try to be “correct;” try to express what you REALLY believe. One piece of IMPORTANT information: Earth and all the other planets orbit the sun in a flat plane; Earth is never significantly “above” or “below” the level of the sun. Keep this in mind when you demonstrate your ideas; i.e. as you demonstrate Earth's orbit, keep the model Earth at the same height as the model sun (the light bulb). Expect to get up and move your styrofoam Earth around the “Sun” to try out your ideas!

Directions: Try to reach consensus within your group and construct a new *group* model that explains Earth's seasons. Describe and illustrate this model on the empty page below.

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[Use this space to draw and describe your group model]

Part 2: Testing, Refining and Applying Your Model of the Causes of the Seasons

Part of the scientific process is to constantly test models to see if they can account for all observations. If they do not, we modify them. During this activity, you will be testing your model and modifying it (or starting over) as necessary in order to account for all the observations listed below.

Materials: Glowing light bulb (to represent the sun)
Polystyrene ball with a stick through it (the stick represents Earth's axis)

Activity: For each observation below, use the materials above to explain the cause of each observation. If your model is not compatible with a particular observation, refine, add to or change your model as necessary.

A. **The Shape of Earth's Orbital Path**: The data we worked with earlier about "the distance" from Earth to the sun was the **average** distance over the course of a year. But the actual distance varies *during* the year because Earth's orbit isn't perfectly circular[1]. The table below shows Earth's average distance from the sun during selected months of the year.

Month	**Average (for the month) Earth-Sun Distance**[2]
January	147,000,000 km
March	149,000,000 km
June	153,000,000 km
July	153,000,000 km
September	150,000,000 km
December	148,000,000 km

1. When is Earth closest to the sun? ______________________________

   When is Earth farthest from the sun? ___________________________

2. Can the distance between Earth and the sun account for the seasons? ________________
   Explain the reasoning behind your answer.

[1]Note: Earth's orbit around the sun is nearly a perfect circle; it is off by only 4%. Astronomers have calculated the resulting difference in incoming solar radiation: it is only 7%. *For those who are curious*, astronomers calculate these distances from the size of the sun as seen from Earth (objects look bigger when they're closer and smaller when they're farther away).

[2]Source: Fraknoi, A. (ed.), 1995, The Universe at Your Fingertips: An Astronomy Activity and Resource Notebook: San Francisco, Astronomical Society of the Pacific

B. **The North Star Stands Still**: At any particular latitude of the northern hemisphere, the North Star is always in the same place in the sky: Azimuth angle 0 (north), always the same elevation angle (your latitude) above the horizon; No matter what time of day you look or what day of the year it is.

   Does your current working model "predict" this result? If so, use the polystyrene ball and the light to show how your model explains why the North Star "stands still." If your group model does not predict this result, construct a new model that does and describe how this new model can explain why the North Star stands still.

C. **Timing of the Seasons in the Northern and Southern Hemispheres**: When it is summer in Indiana (northern hemisphere), it is winter in Argentina (southern hemisphere) and vice versa.

   Does your current working model "predict" this result? If so, use the polystyrene ball and the light to show how your model explains why summer and winter are reversed in the northern and southern hemispheres. If your group model does not predict this result, construct a new model that does and describe how this new model can explain why the seasons are reversed in the northern and southern hemispheres.

D. Lengths of Days and Nights

- Some definitions:

  Summer solstice (approximately June21) At solar noon the sun has the highest elevation angle it will have all year.

  Autumnal equinox (approx. Sept 21) ¼ year after the summer solstice and ¼ year before the winter solstice.

  Winter solstice (approximately Dec 21) At solar noon the sun has the lowest elevation angle it will have all year.

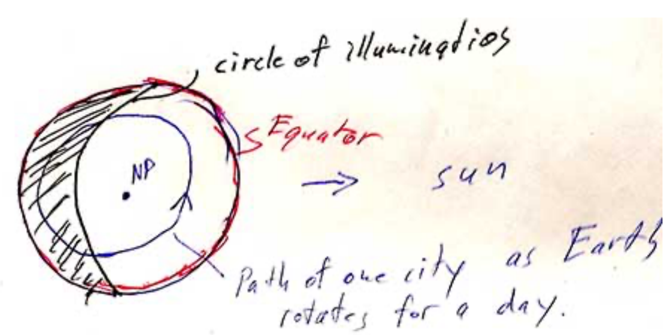
  Vernal equinox (approx. March 21) ¼ year after the winter solstice and ¼ year before the summer solstice.

- [Experiences from Ecuador / Tanzania] At the equator, days and nights each last exactly 12 hours, all year round.
- Everywhere other than the equator, days are longer in summer than in winter. The longest day for us in the northern hemisphere is on the summer solstice (June 21); the longest day for the southern hemisphere is on the winter solstice. For example, at 40° N Latitude (e.g. San Francisco, Denver, New York), the days are almost 15 hours long on June 21, but they are less than 9 ½ hours long on December 21. The closer you get to the poles, the more pronounced this difference is. For example, in Anchorage, Alaska (61° N Latitude), the days are 18 ½ hours long on June 21, but they are only 5 ½ hours long on December 21.
- At the North Pole, it is dark from the autumnal equinox (around September 21) through the vernal equinox (around March 21) and light from the vernal equinox to the autumnal equinox. When it is light at the North Pole, it is dark at the South Pole and visa versa.
- At all locations on Earth other than the poles, there are exactly 12 hours between sunrise and sunset on the dates of the equinoxes.

Draw a dot on the polystyrene ball to represent your town; be sure to place it at the appropriate latitude (consult a globe as necessary). Place the polystyrene ball in the appropriate positions relative to the light to represent the solstices and equinoxes. Note that you can easily see **the *circle of illumination* (the line between day and night)** on the ball. At each position, spin the ball on its axis to model Earth's daily rotation. Complete the table below.

Your "sketch" should show a view of the earth with a.) your town's location and the path it follows as Earth rotates. b.) The circle of illumination. c.) The direction to the sun.

It might be simplest to draw things from a point of view directly above the North Pole (NP). From this point of view, you are looking down as Earth rotates counterclockwise beneath you and the equator is at the edge of the Earth. The rough sketch shown is of a time of year when daytime lasts longer than night time for the city shown, and the North Pole is in daytime for all 24 hours.



Season	Proportion of each 24-hour day that your town spends in the light vs. the dark		Sketch of Northern Hemisphere
Winter Solstice	% of time in the light		
	% of time in the dark		
Spring Equinox	% of time in the light		
	% of time in the dark		
Summer Solstice	% of time in the light		
	% of time in the dark		
Fall Equinox	% of time in the light		
	% of time in the dark		

Question: Can the change in the number of hours of daylight over the course of a year **help** (it doesn't have to be the only factor) explain the differences in temperature between summer and winter? If so, explain how. If not, explain why not.

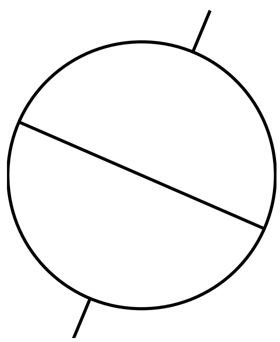
E. Attributes of the Tropics of Cancer and Capricorn:

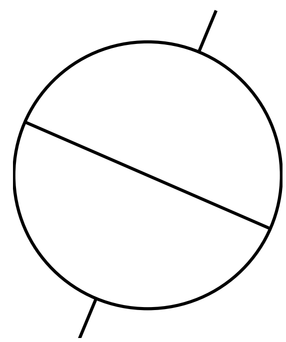
- At 23.5° North latitude (the Tropic of Cancer), the sun is directly overhead at noon on the summer solstice (around June 21).
- At 23.5° South latitude (the Tropic of Capricorn), the sun is directly overhead at noon on the winter solstice (around December 21).

Activity: Draw two circles on your polystyrene ball in the appropriate positions to represent the Tropic of Cancer and the Tropic of Capricorn. Place the polystyrene ball in the appropriate positions relative to the light to represent the summer and winter solstices.

Complete the diagram below, adding

- The sun and its rays
- The circle of illumination
- The Tropics of Cancer and Capricorn
- The angle between the sun's rays and the ground at each of the Tropics





Date: ______________

Date: _______________

F. <u>Attributes of the Arctic and Antarctic Circles</u>:

- At 66.5° (66.5=90.0-23.5) North latitude (the Arctic Circle), the sun never sets on the summer solstice (around June 21); on all other days, the sun does go down at least for a little while. Everywhere north of the Arctic Circle, there are even more days when the sun never sets in the summer (the further north you go, the more days there are with 24 hours of light--"Midnight Sun").
- At 66.5° North latitude (the Arctic Circle), the sun never rises on the winter solstice (around December 21); on all other days, the sun does make an appearance. Everywhere north of the Arctic Circle, there are even more winter days when the sun never rises (the further north you go, the more days there are with 24 hours of darkness).
- At 66.5° South latitude (the Antarctic Circle), the situation is similar but reversed (substitute June 21 for Dec. 21 and visa versa).

<u>Activity</u>: Draw two circles on your polystyrene ball in the appropriate positions to represent the Arctic and Antarctic circles. Place the polystyrene ball in the appropriate positions relative to the light to represent the summer and winter solstices. Rotate the ball on its axis to represent Earth's rotation.

<u>Question</u>: What is special about the Arctic and Antarctic Circles (at the solstices) that can explain the above observations?

Complete the diagram below, adding

- The sun and its rays
- The circle of illumination
- The Arctic and Antarctic Circles

Date: ______________ Date: _______________

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