SEASONS
Session 1: Space-Based Perspectives

1. Draw a space-based diagram that shows why we experience day and night on Earth.

Make sure that you:

- ☐ **Include all objects** that you think are important to show your reasoning.
- ☐ **Label** the key parts of your diagram.
- ☐ **Shade** your diagram to show the unlit (nighttime) part.
- ☐ **Draw a triangle** on a location (a city) that is currently experiencing daytime.
- ☐ **Draw an X** on a location (a city) that is currently experiencing nighttime.
- ☐ Think about how a city like Boston experiences a day-night cycle. **Add arrows** to your diagram to show the movement of the Earth that explains **why** Boston experiences a day-night cycle. Think carefully about *which direction* things should move.

SEASONS
Session 2 - 3: Apparent Path of the Sun in the Sky

A. Make a prediction:

I think the Sun's apparent path in the sky each day is __________________ throughout the year.
< the same / different >

If you think it is the same, explain *why* it is the same.
If you think it is different, describe *how* it is different.

____

____

____

____

____

B. Collect data for Boston:

Season and date	**Marker Color** (on SunTracker)	**Sun Angle at Midday** (in degrees)	**Length of Day** (in hours)
Winter (December 21)	**blue**		
Spring (March 21)	**green**		
Summer (June 21)	**red**		
Fall (September 21)	**black**		

C. Compare and analyze data for Boston:

1. Which season has the highest Sun angle at midday? ______________________
2. Which season has the lowest Sun angle at midday? ______________________
3. Which season has the longest day length? ______________________
4. Which season has the shortest day length? ______________________
5. Which seasons have the same Sun angle at midday / day length? ______________________
6. Was the Sun ever directly overhead in Boston? ______________________

D. Record your ideas:

How do you think the Sun's height in the sky and the length of day affect temperature on Earth?

1. Here are some ways I think the Sun's **height in the sky** affects temperature:

   ____

   ____

2. Here are some ways I think the **length of day** affects temperature:

   ____

   ____

North

East

South

West

SEASONS
Session 4: Sun Angle and Energy

Activity: Modeling Light from the Sun

In this activity you will use a flashlight and grid paper to model sunlight hitting the ground at different angles. You will explore how Sun angle affects the amount of ground illuminated by the Sun, which determines the amount of energy we receive from the Sun (and therefore, temperature).

A. Procedure:

1. Place the gridded paper on your desk. Place the bottom of the meter stick where the gridded paper tells you to.
2. Use a protractor (or half-SunTracker) to position the meter stick pointing straight up, at an angle of 90°. Turn off the room lights and turn on the flashlight. This represents a Sun angle of 90°.
3. Use a pencil to draw an outline around the area illuminated on the gridded paper. Label the outline with the current Sun angle.
4. Repeat step 2 at 60°, 30°, and 10°. Use your protractor (or half-SunTracker) to measure the angle. Keep the bottom of the meter stick on the bold line of the gridded paper for each trial.
5. Turn on the lights when everyone is finished.
6. For each Sun angle, count the number of squares illuminated by the flashlight, estimating if some squares are only partially lit. Record data in the table below.
7. For each Sun angle, determine the fraction of light striking each square and record it in the table. For example, if the flashlight illuminated 15 squares, then each square receives 1/15 of the light.

B. Collect data:

Complete this table with your group:

Sun Angle (in degrees)	**Number of Squares Illuminated** (area in cm^2)	**Fraction of Total Light Received by Each Square** (as a fraction)
90°		
60°		
30°		
10°		

C. Compare and analyze:

At which Sun angle was the largest area of ground illuminated? ____________________

At which Sun angle was the smallest area of ground illuminated? ____________________

At which Sun angle did each square of ground receive the most amount of light (and therefore, the most intense light)? ____________________

When sunlight is more intense, the temperature will be (warmer / cooler). ____________________

At which Sun angle did each square of ground receive the least amount of light (and therefore, the least intense light)? ____________________

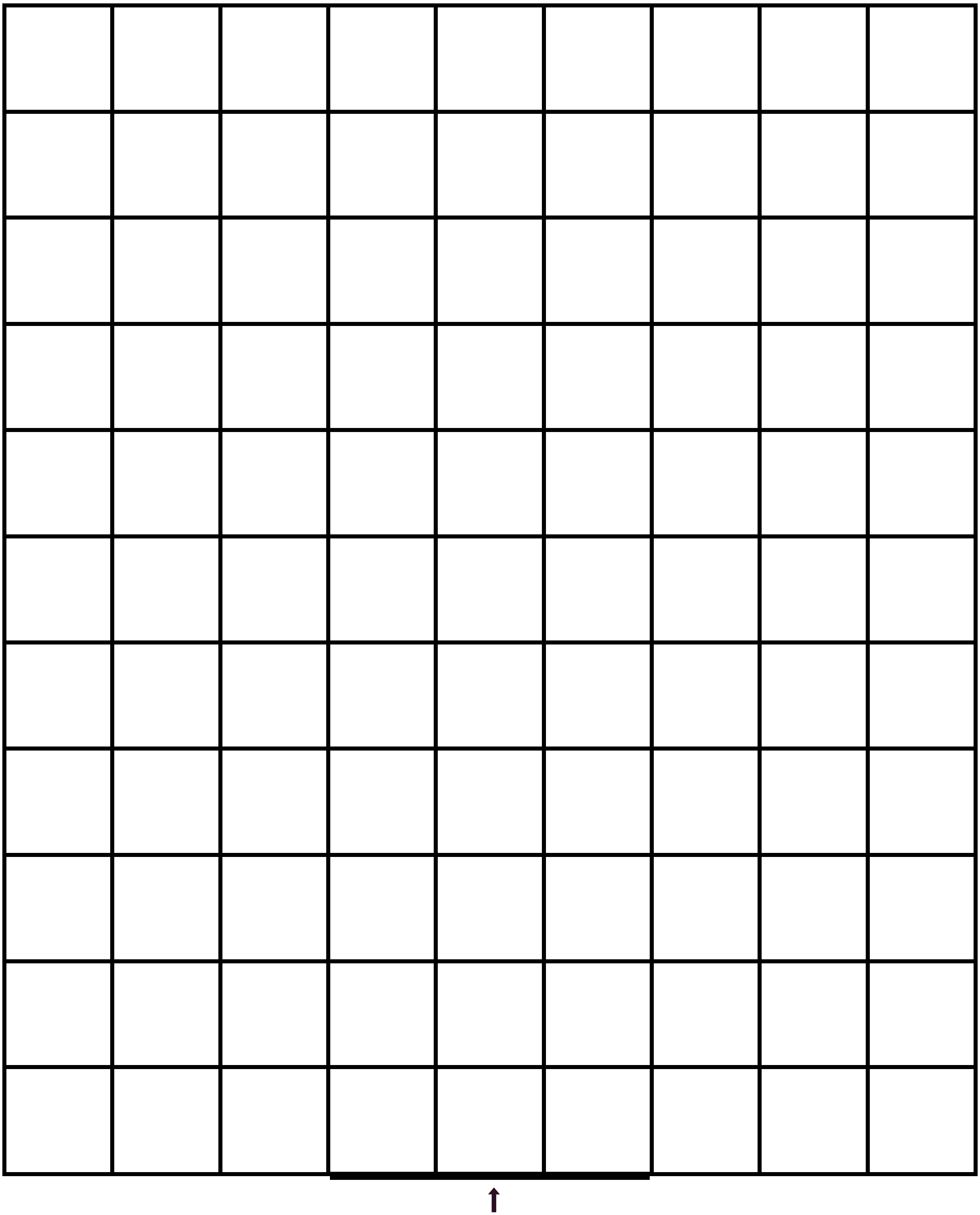
When sunlight is less intense, the temperature will be (warmer / cooler). ____________________

D. Record your ideas:

Based on **what we have learned so far**, explain ***why*** you think it is warmer in the summer than in the winter.

Try to connect what you have learned about:

(1) how the Sun appears to move in the sky during different seasons;
(2) how the Earth's axis affects the mid-day Sun angle; and
(3) how the Sun's angle in the sky affects the intensity of light we receive.



PLACE BOTTOM OF METER STICK HERE

Name: ______________________________

SEASONS
Session 5: Earth's Tilted Axis

1. Model a Year

Model Earth orbiting the Sun, using the Seasons sheet on your table as a guide.
Note: Be sure to always point your Earth's axis in the direction indicated by the instructor.

- ☐ Place your team's Seasons Sheet on the table. Match the orientation of the seasons on the sheet to the signs hung around the room. Place a ring on the Seasons sheet. Place your Sun on the ring.
- ☐ Each team member should stand around your table at one of the season positions marked on the sheet. Each team member should represent a different season.
- ☐ Summer team member:
  - ☐ Hold Earth on the side of the Sun that represents Summer. Orient the tilt of Earth's axis in the direction indicated by the instructor.
  - ☐ Holding the dowel that represents Earth's axis, move Earth through your season to model how Earth orbits around the Sun during Summer.
  - ☐ Pass Earth to the Fall team member, always keeping the axis pointed in the correct direction.
- ☐ Fall, Winter, and Spring team members:
  - ☐ Take turns repeating the steps above during your season. Fall team member will model Earth's orbit during Fall, then pass Earth to Winter team member, and so on.
  - ☐ Make to complete a full Year by passing Earth through every season and back to Summer.

2. Model a Day at Different Times of Year

- ☐ Summer team member: Rotate Earth at the Summer position, so your Lego person experiences both night and day. All teammates should make sure that the axis orientation remains correct.
- ☐ Fall team member: Rotate Earth at the Fall position, so your Lego person experiences both night and day. All teammates should make sure that the axis orientation remains correct.
- ☐ Pass and repeat for the other two seasons.

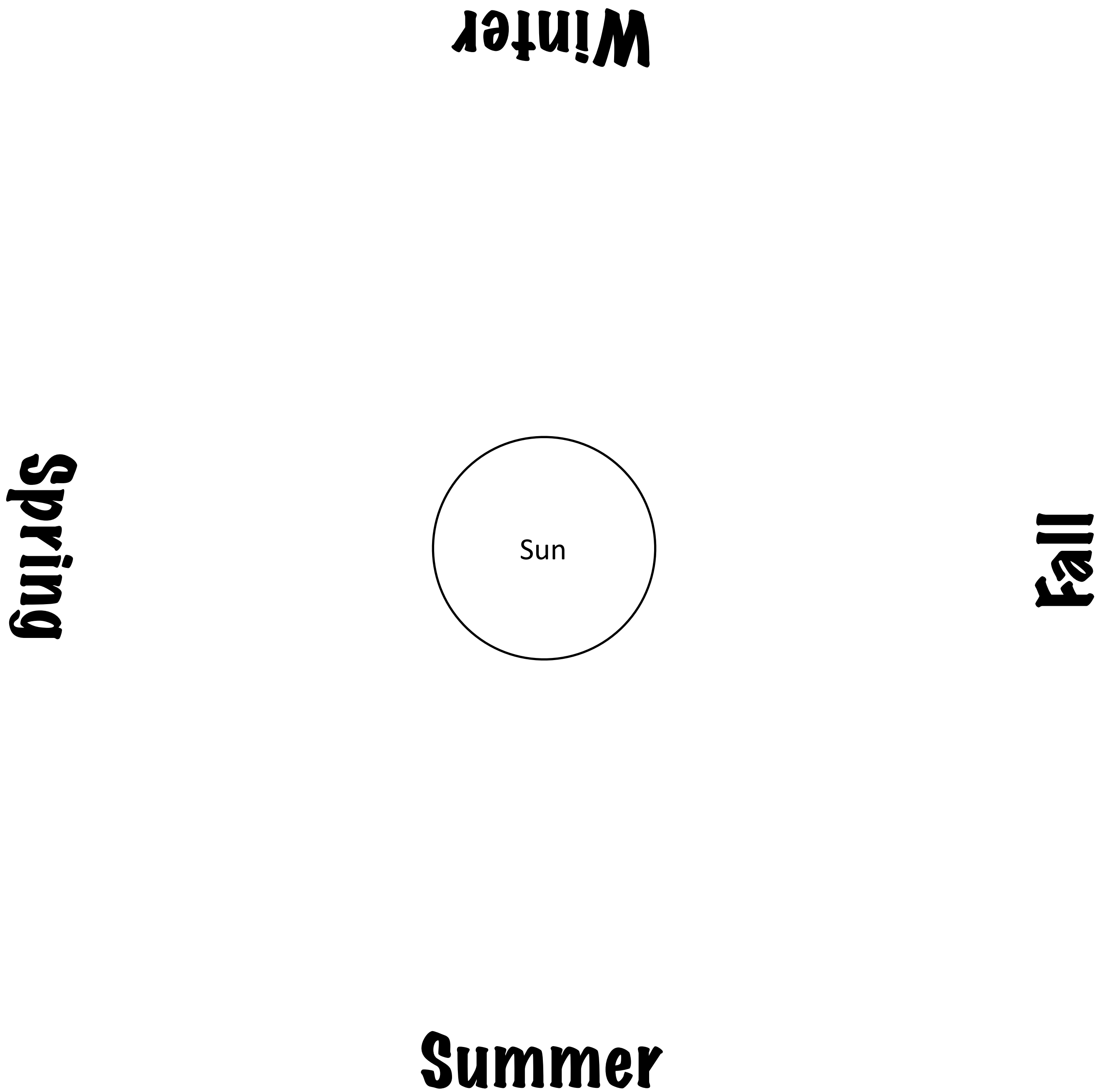
3. Observe from the Model

When Earth experiences **Summer** in the Northern Hemisphere:

1. The Northern Axis is tilted ______________________ the Sun.
   < towards / away from >
2. The Southern Axis is tilted ______________________ the Sun.
   < towards / away from >
3. To see the Sun at midday, Lego person must look _____________ , _____________ in the sky.
   < up / ahead > < high / low >

When Earth experiences **Winter** in the Northern Hemisphere:

1. The Northern Axis is tilted ______________________ the Sun.
   < towards / away from >
2. The Southern Axis is tilted ______________________ the Sun.
   < towards / away from >
3. To see the Sun at midday, Lego person must look _____________ , _____________ in the sky.
   < up / ahead > < high / low >


Winter
Spring
Sun
Fall
Summer

Summer

Fall

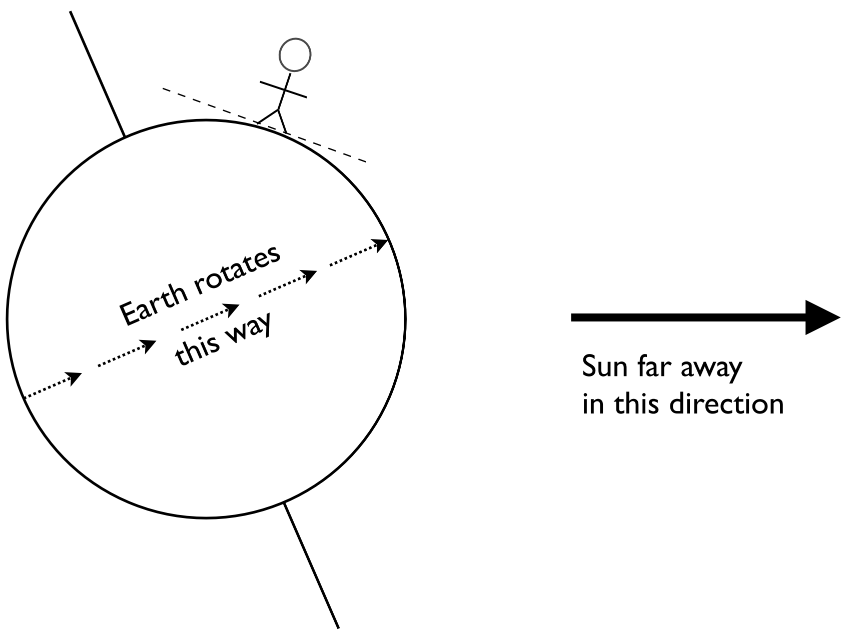
Winter

Spring

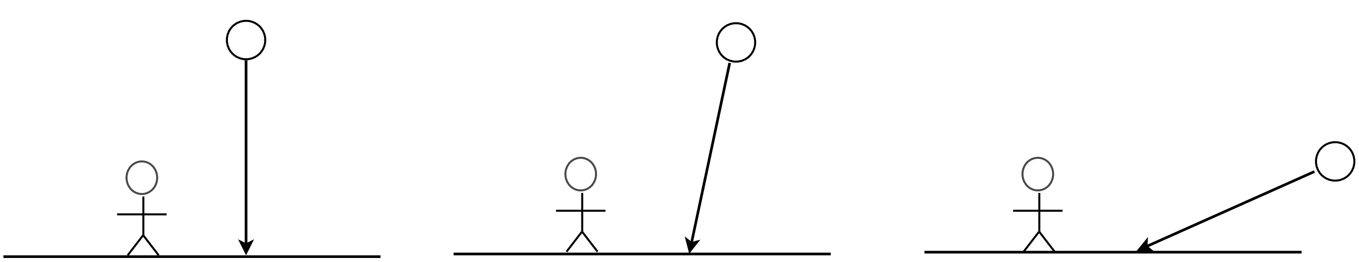
SEASONS
Session 6: Tilted Axis and Sun Angle

A. Interpret This Diagram:

Diagram **NOT** to scale.



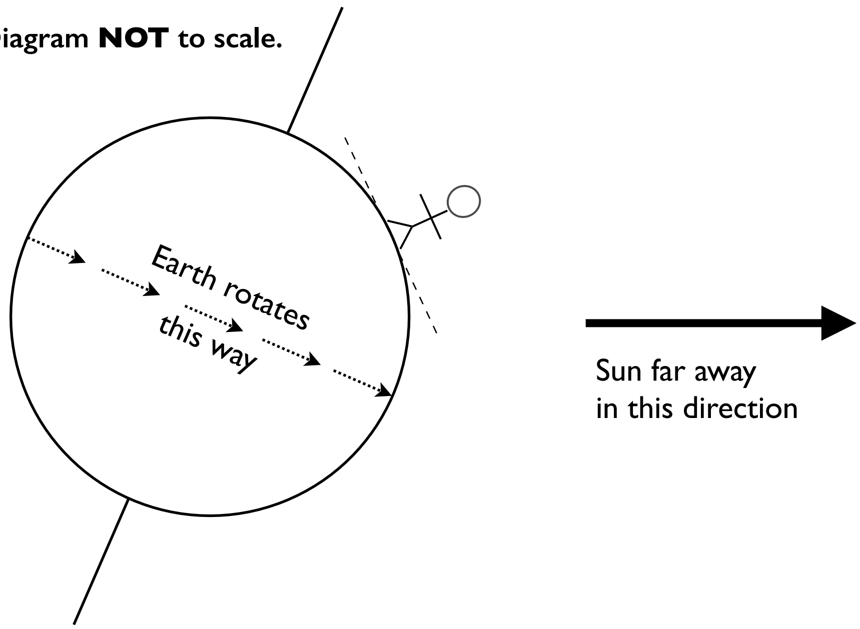
1. The Northern Hemisphere is tilted ______________________ the Sun.
   < towards / away from >
2. Sketch in **five light rays** from the Sun, to show how you think sunlight reaches Earth.
3. Shade the diagram to show which part of Earth is **dark**.
4. What time of day do you think it is for the stick person above? ______________________
   < sunrise / midday / sunset / midnight >
5. Circle which of the three figures below you think best represents the angle of sunlight hitting the person's ground at the moment shown above. The angle of sunlight is the same as the Sun Angle.



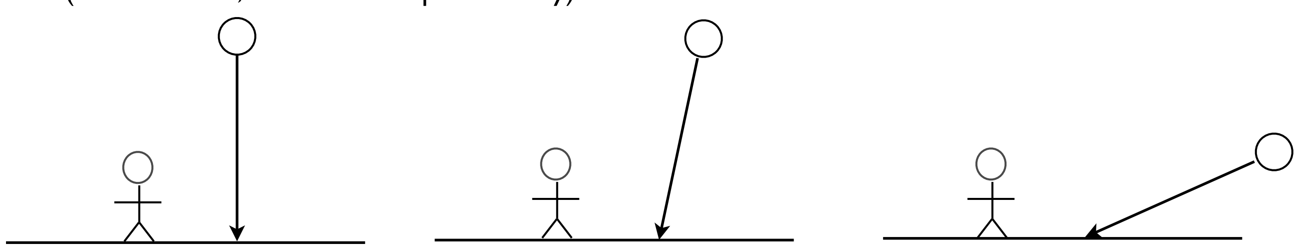
6. What season do you think it is for the stick person? ______________________
   < summer / winter >

B. Interpret this diagram:

Diagram **NOT** to scale.



1. The Northern Hemisphere is tilted ____________________ the Sun.
   < towards / away from >
2. Sketch in **five light rays** from the Sun, to show how you think sunlight reaches Earth.
3. Shade the diagram to show which part of Earth is **dark**.
4. What time of day do you think it is for the stick person above? ____________________
   < sunrise / midday / sunset / midnight >
5. Circle the figure that you think best represents the angle of sunlight hitting the person's ground (and therefore, the Sun in the person's sky) at the moment shown above.



6. What season do you think it is for the person? ____________________
   < summer / winter >

C. Compare:

When the Northern Hemisphere is tilted **towards** the Sun, the Sun is _______________ in the sky at midday. This is _______________ .
< high / low > < summer / winter >

When the Northern Hemisphere is tilted **away from** the Sun, the Sun is _______________ in the sky at midday. This is _______________ .
< high / low > < summer / winter >

Name: ______________________________

SEASONS
Session 6: Bonus Questions

Figure 1

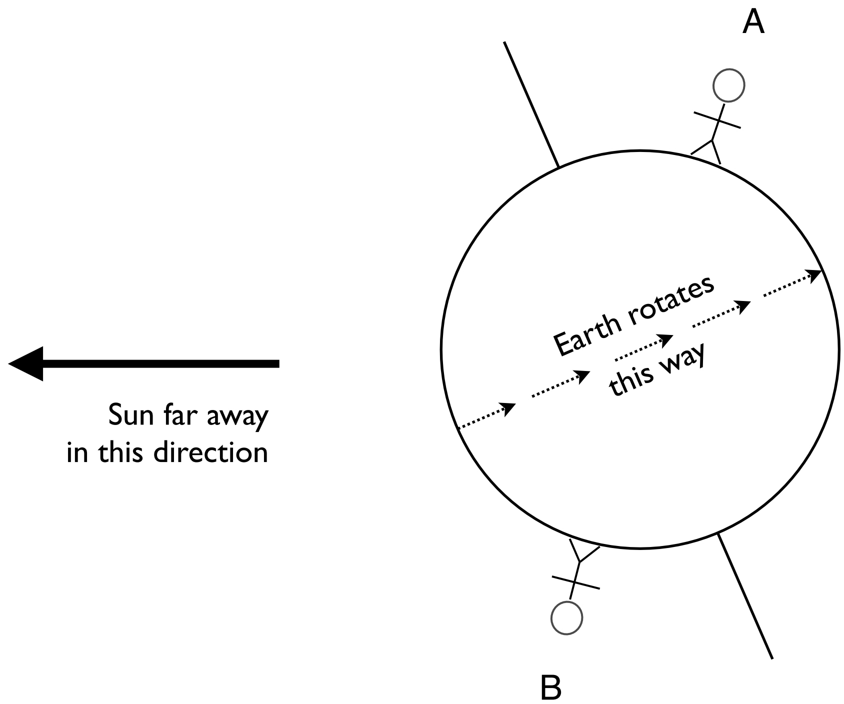


Diagram NOT to scale.

1. Sketch in **five light rays** from the Sun.

2. Shade the **dark part** of Earth.

3. What time of day is it for Person A? ________________

4. What season is it for Person A? ________________

   Explain why you think so:

   ____

   ____

5. What time of day is it for Person B? ________________

6. What season is it for Person B? ________________

   Explain why you think so:

   ____

   ____

Figure 2

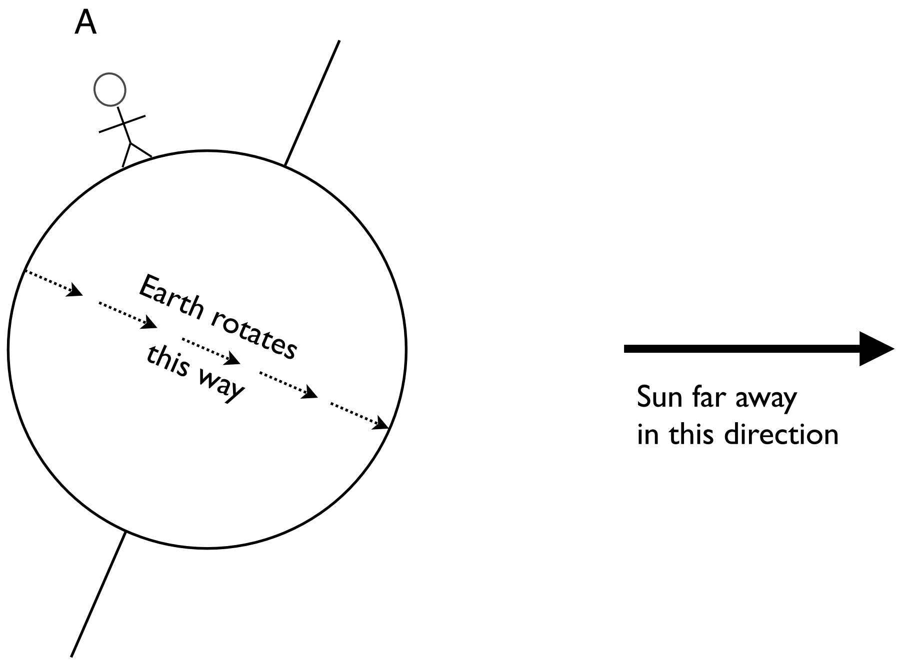


Diagram **NOT** to scale.

1. Sketch in **five light rays** from the Sun.
2. Shade the **dark part** of Earth.
3. **True or False?** Figure 1 and Figure 2 show the same time of day and the same season for Person A. ________________
4. Sketch in a person for whom the Sun is **directly overhead** on this day. Label this Person B.
5. Sketch in a person who will **never see the Sun** on this day. Label this Person C.
6. Sketch in a person who will **never experience darkness** on this day. Label this Person D.

Name: ______________________________

SEASONS
Session 7: Tilt and Day Length

1. Collect Data: Total hours of daylight around the world

on June 21

A. The Northern Hemisphere is tilted ________________ the Sun.
< toward / away from >

B. A place that spends this **entire day in darkness** (never sees the Sun) is _________________ .

This place is in the ________________ Hemisphere, close to the ______________________ .
< Northern / Southern > < North Pole / South Pole / Equator >

C. A place that spends less time in daylight than darkness is _____________________ .

This place is in the ________________ Hemisphere, which is tilted ________________ the Sun.
< Northern / Southern > < toward / away from >

on December 21

D. The Northern Hemisphere is tilted ________________ the Sun.
< toward / away from >

E. A place that spends more time in daylight than darkness is _____________________ .

This place is in the ________________ Hemisphere, which is tilted ________________ the Sun.
< Northern / Southern > < toward / away from >

F. A place that spends the same amount of time in daylight as darkness is ________________ .

This place is located near the ______________________ .
< North Pole / South Pole / Equator >

G. A place that spends the **entire day in daylight** (never sees the Sun set) is ________________ .

Sept. 21

H. Barrow, Alaska spends ___________________________ time in daylight than darkness.
< more / the same amount of / less >

I. Puerto Montt, Chile spends ___________________________ time in daylight than darkness.
< more / the same amount of / less >

2. Compare

A. When the Northern Hemisphere is tilted toward the Sun, the Southern Hemisphere is tilted ______________________ the Sun.
< toward / away from >

B. Cities in the hemisphere tilted **toward the Sun** have ______________________ hours of
< more / the same amount of / fewer >
daylight than darkness.

C. Cities in the hemisphere tilted **away from the Sun** have ______________________
< more / the same amount of / fewer >
hours of daylight than darkness.

D. Some places on Earth have roughly equal amounts of daylight and darkness every day of the year. These places are close to the ______________________ .
< Equator / Poles >

E. There are places on Earth where on certain days of the year, the Sun never rises or never sets for an entire day. These places are close to the ______________________ .
< Equator / Poles >

F. On September 21 and March 21, the total hours of daylight are ______________________
< more than / the same as / fewer than >
the total hours of darkness everywhere on Earth.

These dates are known as the ______________________ .

SEASONS
Session 8: Earth's Orbit

1. What shape is Earth's orbit?

A. Draw a diagram of Earth's orbit around the Sun from an **overhead** perspective.

B. Label all the key parts of your diagram.

C. Label where you think Earth is when it's September, December, March, and June.

2. Distance from Earth to the Sun

Predict: In what month (if ever) do you think Earth is closest to the Sun? ______________________

Date (and season in Boston)	**Collect Data** distance from Earth to the Sun (in kilometers)
December 21 Boston winter	
March 21 Boston spring	
June 21 Boston summer	
September 21 Boston fall	

3. Compare and analyze

Use the data in your table on the previous page to answer these questions:

Earth is closest to the Sun when it is ______________________ in the Northern Hemisphere.
< fall / winter / spring / summer >

Earth is farthest from the Sun when it is ______________________ in the Northern Hemisphere.
< fall / winter / spring / summer >

4. Reflect

A common belief for why we experience Seasons is that Earth is closer to the Sun in the summer, and farther away in the winter.

Do you agree or disagree with this? ________________________
< agree / disagree >

Explain your reasoning. If you disagree, please explain **why** you think we have seasons.

____

____

____

____

5. Recap

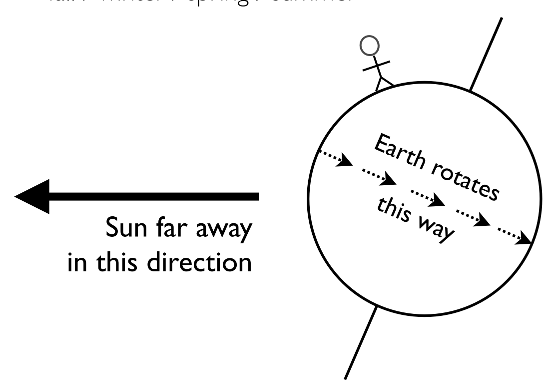
i. What season is it for the person in the diagram to the right? ______________________
< fall / winter / spring / summer >

ii. The person in this diagram will experience *(circle one)*:

a. A longer day and shorter night

b. Roughly an equal day and night

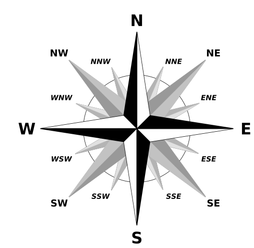
c. A longer night and shorter day



iii. Sketch a side-view of Earth and the Sun when the Southern Hemisphere is experiencing winter.

SEASONS KEY TERMS

Rotation:	turning or spinning on an axis; Earth's **rotation** is the reason we experience **night/day.**
Revolution/ Orbit:	movement or path around another object; Earth's **revolution** around the sun takes one Earth **year** (365 days).
Axis:	an imaginary line around which the Earth spins or rotates
Sunrise:	when a given point on Earth rotates from the unlit half to the lit half; "daytime" begins.
Sunset:	when a given point on Earth rotates from the lit half to the unlit half; "nighttime" begins.
Cardinal Directions:	Directions of north, east, south, and west. *(See diagram to right).*
Horizon:	An imaginary line where the sky and the ground appear to meet. (Has a sky angle of 0 degrees.)
Directly Overhead:	The point in the sky that is straight above. (Has a sky angle of 90 degrees.) Unless you live within 23.5° latitude of the equator, the sun is NEVER directly overhead.
Sky Angle:	Measure (in degrees) of how high above the horizon an object is in the sky.
Sun Angle:	Sky angle of the Sun.
Equinox:	2 days of the year when we experience equal hours of daylight and night time (12 hours each) - March 21 and Sept 21
Tilted Axis:	Earth's axis is tilted at 23.5 degrees and is always pointed toward the North Star, Polaris. 

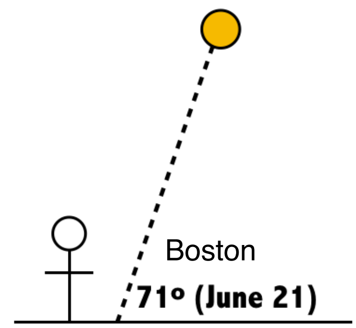


Cardinal Directions

SEASONS KEY IDEAS

Summer - Hot

- Higher sun angle at midday
  - Light concentrated over a small area -> more intense -> warmer
- Longer sun path -> Longer hours of daylight
  - More time to heat up the ground

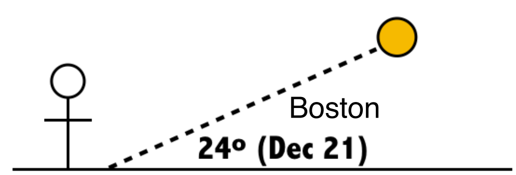


Fall/Spring - In between

- Medium height sun angle at midday
- Medium length sun path -> medium hours of daylight
- Equinoxes: September 21/March 21 - Equal hours of day/night - 12 hours each

Winter - Cold

- Lower sun angle at midday
  - Light spread out over a larger area -> less intense -> cooler
- Shorter sun path -> Fewer hours of daylight
  - Less time to heat up the ground



Name ________________________________

SEASONS
Extension Questions

For each of these questions, sketch a diagram to help us understand your thinking.

1. Determine the relationship between a city's latitude and the Sun's angle at midday for the equinoxes. How does the midday Sun angle differ between the equinoxes and the solstices?
2. Describe the locations on Earth (in terms of latitude) where the Sun can be directly overhead.
3. Describe the locations on Earth (in terms of latitude) where it is possible for the Sun to never rise for an entire day at certain times of year.
4. Uranus has an axis tilt of 98 degrees (meaning it basically spins on its side). Describe the seasons on Uranus for a visitor to the "northern" hemisphere, equator, and "southern" hemisphere.
5. Imagine a planet around a sun-like star in our galaxy.
   - Decide what kind of orbit shape the planet has (anywhere from essentially circular to highly elliptical). Assume the planet orbits at an average distance comparable to Earth's distance from the Sun.
   - Decide what axis tilt the planet has.

   Do you think life could evolve on a planet with your chosen characteristics? What kind of adaptations would be necessary to help a species thrive on this planet?