ThinkSpace Seasons Curriculum

CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

wwtambassadors.org
worldwidetelescope.org

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Student Objectives: Why Do We Experience Seasons?

Combining Earth-Based and Space-Based Perspectives for Deeper Understanding

Students will be able to:

- Accurately describe how the Sun appears to move in the Boston sky throughout the year from an Earth-based perspective
  - Sun has a longer apparent path in the summer; shorter in winter.
  - Sun reaches a higher mid-day sun angle in the summer; lower in winter.
  - Higher sun angle translates to more direct light which translates to greater heat transfer
- Accurately describe how the Earth moves relative to the Sun from a space-based perspective
  - Earth rotates on a tilted axis, which leads to night/day.
  - Earth revolves around the Sun, which takes place over a year.
  - The tilted axis always points in the same fixed direction in space, so sometimes our part of the Earth is tilted towards the sun (summer) or away from the sun (winter).
  - Earth's orbit around the Sun is very close to circular.
  - The Earth and Sun are so far apart that Earth's tilted axis does not bring our part of the Earth significantly closer to the Sun.
- Develop & use physical and virtual models to explain WHY the tilted axis leads to Seasons phenomena
  - WHY does the sun angle in the sky change throughout the year? (Sun angle higher in the summer/lower in winter)
  - WHY are the days longer in the summer and shorter in the winter?
- Investigate energy transfer as it relates to Sun angle and experience of seasons
  - WHY does a higher sun angle lead to higher temperatures?
- (Extension) Use models to explain why different parts of the world experience seasons differently

Misconceptions addressed:

- What is the shape of Earth's orbit?
- Is distance a critical factor in explaining what causes Seasons?
  - What is the shape of Earth's orbit? Is Earth closer to the sun in the summer?
  - Does the tilted axis bring our hemisphere closer to the sun in the summer?

Consider in advance:

- What pairings of students will work well together throughout the 8-day unit? Choose students who will discuss concepts with each other and take turns well.
- On Day 4, the activity will be in groups of 4. Consider which pairs of students would work well with another pairing of students.

Materials:

Material lists are also included in the day-by-day curriculum below. This list includes all materials throughout the 8-day unit.

All days:

- Computer
- Projector
- Speakers

Day 1:

- Lantern/Lightbulb
- 6” globe
- Lego figure “Vicky” with Sticky Tack

Days 2 & 3 (Per pair of students):

- Half-dome Clear Plastic Suntracker
- Lego Vicky
- 4 Colors of Dry Erase Markers
- Tissues or Paper towels (to clean Suntrackers)

Day 4:

- Flashlight
- Meter stick
- Square grid of paper

Days 5 & 6 (Per pair of students):

- Foam Earth speared with dowel
- Small yellow ball to represent Sun, with a ring to keep from rolling
- Stack of books to raise model Sun to height just below students’ sternum when they are standing up
- Lego Vicky with Sticky Tack

Day 7:

- One device (laptop, chromebook, etc) per group of students

Day 8:

None

Video Links:

Each video link also appears in the day-by-day curriculum below. This list consolidates all videos throughout the 8-day unit.

Session 1

Session 1: Rotation and Revolution
Session 1 - Instructional DEMO for Teachers

Sessions 2 & 3

March 21
June 21
September 21
December 21
Comparisons

Session 4

No WWT Content for Session 4

Session 5

Session 5: Earth's tilted axis
Session 5: Instructional DEMO for Teachers - Using the Model
Session 5: Instructional DEMO for Teachers - Common Mistakes

Session 6

Session 6: Modeling Sun Angle

Session 7

Session 7: Hours of Daylight

Session 8

Session 8: Distance and Seasons Part 1
Session 8: Distance and Seasons Part 2

Activity Sheets:

All activity sheets also appear in the corresponding sessions below. This list consolidates all activity sheets throughout the 8-day unit.

Full Course

Complete Set (Sessions 1-8)
Key Terms and Concepts (Resource tool for teachers)

Session 1

Session 1: Space-Based Perspectives

Sessions 2 & 3

Session 2-3: Apparent Path of the Sun in the Sky
Session 2: Cardinal Directions Signs

Session 4

Session 4: Sun Angle and Energy
Session 4: Square Grid

Session 5

Session 5: Earth's Tilted Axis
Session 5: Model Placemat
Session 5: Seasons Signs

Session 6

Session 6: Tilted Axis and Sun Angle
Session 6: Bonus Questions

Session 7

Session 7: Tilt and Day Length

Session 8

Session 8: Earth's Orbit

Seasons Day-by-Day Curriculum:

Color Code Key for Lesson Plans

Activity Sheets
Models, Materials, Hands-on Activity
Videos and other links
Instructor Suggestions and Answers

SESSION 1: Modeling the Earth-Sun System

Total Class time: 45-50 minutes

Goals:
- Introduce unit on Seasons
- Discuss value of models in science and possible pitfalls to be aware of
- Explore physical model of Earth-Sun
  - Rotation -> day/night
  - Revolution -> year
- View virtual model of Earth-Sun in WorldWide Telescope

Addressing Misconceptions:
- Rotation vs. Revolution - focus on the outcome of the movement, rather than trying to memorize the 2 similar "R" words.
  - Which motion causes night/day?
  - Which motion takes a year?

Materials:

Physical Model
- Lantern to represent Sun, placed in middle of room
- 6" globe
- Lego Vicky with sticky tack to attach to globe

- Optional activity to have students use model in pairs to figure out which way Earth rotates (clockwise or counterclockwise when viewed from above):
  - For each pair of students:
    - A 3" foam Earth speared with a dowel
    - A foam Sun

Virtual Model

- Computer to project Day 1 WWT lesson
- Projector
- Speakers

For each student

- Day 1 Activity Sheets

Classroom Setup:

- Connect computer to projector & speakers
- Link computer to Day 1 WWT lesson
- Set up Sun lantern in middle of classroom

	Materials Needed	Format	Lesson Outline
1a		**Teacher Leads Class Discussion** (5 min)	**Seasons Unit Learning Target: Why do we experience the seasons we do in Massachusetts?** [Bonus Goal: Why do people elsewhere in the world experience the seasons they do?] Gather Basket of Ideas about seasons: ● What do you already think? ● What have you heard from others? ● What do you notice is different in summer/winter? ● What time does it get dark? ● Is this the same all year? *"Your job over the next two weeks is to take the ideas shared today and be able to use a variety of models to figure out which ideas are true/untrue and why."*
1b	*-Toy Helicopter (non-operational)* *-Hat* *-Candle, etc.* *-something that has words only on top (not on the side)*	***Optional*** *Class discussion & interaction* *(5 min)*	***Perspective-Taking –*** *What Does the helicopter See?* ● *General concept of Perspective Taking* ○ *Arrange objects around room. Place helicopter in one location.* ○ *Which object would appear farthest to the right to the helicopter?* ○ *Who in the room has the easiest time answering this question? (people on the same side of the room as the helicopter=> same perspective)*

			○ *People elsewhere in the room have to do a mental exercise ("perspective-taking") to imagine what they would see if they were in the same location as the helicopter.* ● *Overhead vs side-views.* ○ *In space (or for flying objects, like the helicopter) , perspective isn't just "right vs left/in front of vs behind." There can also be an "overhead" view.* ○ *Put helicopter next to the object that has words only on top. Can the helicopter pilot read the words from this location? NO. Where do they have to be? OVERHEAD.* ● *Relevance of Perspective Taking to Seasons* ○ *Connect earth-based view and space-based view - Being able to switch between earth-based and space-based perspectives is necessary to understanding what causes Seasons* ○ *Also, sometimes what's on the right vs. what's on the left changes.* ○ *Think about Sun-Earth model. Earth goes around the Sun, and its position changes at different times of year. Consider this particular moment during the year. Put the helicopter on one side, looking at Sun-Earth together. Which object is on the right? <students answer>* ○ *Now freeze time (so the time of year hasn't changed), and put the helicopter on the opposite side. Now which object is on the right? <it switches> Remember, sometimes you are looking at the Earth-Sun from different perspectives, so that changes which object is right or left, but that doesn't mean you are looking at a different time of year. Keep that in mind for the 2nd half of the Seasons unit.*
1c		**Teacher Leads Class Discussion** (5 min)	**Today's Learning Target: Modeling Night and Day** **Introduction to Models** ● From a science perspective, what's a model? Why do scientists use models? ● What are some strengths/limitations of models? ○ *Ex. strengths: you can physically manipulate a model of the Earth/Sun (as opposed to the real thing); you can model different times of year in a few seconds rather than waiting for the real thing to change* ○ *Ex. limitations: scale of the model is wrong. Earth/Sun much, much farther apart than real life than the model would indicate. (To get the earth-sun distance scale to fit in the classroom, the Earth/Sun objects would be tiny specks you can't see detail on.)* ● We'll be using a few different models to understand all the factors that cause us to experience seasons. ● Be aware of where a model's inaccuracies might accidentally lead us astray. ○ *This lesson plan will call those out throughout the activity descriptions.*

			Discuss: ● Why do we experience night and day on Earth? ○ *As Earth rotates, when your side of the Earth faces toward the Sun, you experience daytime. When your side of the Earth faces away from the Sun, you experience nighttime.*
1d	Setup in classroom: ● Lantern in middle of room to represent Sun ● Earth Globe ● Lego person (sticky Vicky) Give each pair of students: -3" foam earth on a dowel + a foam Sun. (They don't need a Lego person for this part).	**Teacher guides class through a physical model of Earth-Sun System** (20 min) **Student hands on physical model**	**Basic Earth-Sun Model** Discussion of Model ● Explore a physical model of the Earth-Sun system together; make sure everyone is on same page ● What can we use in our physical model to represent the Sun and the Earth? ○ *Lamp/Lantern in middle of room = Sun* ○ *Globe = Earth* ● How does Earth move? ○ *Rotates on Axis => Night/Day* ○ *Goes around Sun => One Year* ● Explore **Rotation; Day/Night** - teacher attaches Lego Vicky to 6" globe using glue dot on Massachusetts (See here for a video meant to help remind teachers how to do this demonstration for students.) ○ Face Vicky/MA toward Sun. What time is Vicky experiencing? *(midday)* ○ Face Vicky/MA away from Sun. What time is Vicky experiencing? *(midnight)* ○ Which direction does Earth rotate? ● Students use models to answer question, "Which direction does Earth rotate?" ○ Give each pair of students a 3" foam earth on a dowel + a foam Sun. (They don't need a Lego person for this part). ○ Ask students to figure out which direction Earth rotates. (Clockwise if viewed from above, or counterclockwise?) ○ Hint: Do you know someone who lives somewhere else on Earth? What time is it there compared to MA? For example, someone in MA should see sun rise before someone in California ■ *(Correct answer: Counterclockwise if looking down from above North pole)* ● Continue teacher demo:

		Teacher demo of physical model of Earth-Sun System	◦ Now that we know which way Earth rotates, let's explore what time of day our Lego person experiences in more detail.
			◦ Turn Earth so Vicky is on the day/night line (going from the nighttime side to the daytime side). What time is Vicky experiencing? *(sunrise)*
			    ▪ Optional Perspective Taking: Which general direction does Vicky have to look toward to see sun as it is rising? *(East - she has to look over the Atlantic Ocean)*
			◦ Keep rotating Earth slowly - point out midday.
			◦ Stop rotating when Vicky is on the day/night line (going from the daytime side to the nighttime side). What time is Vicky experiencing? *(sunset)*
			    ▪ Optional Perspective Taking: Which general direction does Vicky have to look toward to see sun as it is setting? *(West - she has to look over the rest of the US)*
			◦ Keep rotating Earth slowly - point out midnight.
			• Explore **Revolution**
			◦ Show that Earth slowly orbits around the Sun (in the SAME direction that Earth rotates) while it is also rotating on its axis.
			◦ How long does it take Earth to go around once? *(One Year)*
			◦ How much time passes going ¼ of the way around the orbit? *(3 months)*
			◦ How much time passes going from one part of the orbit to the side directly opposite? *(6 months)*

1e		***Show** WWT via projector (7 min)	**WorldWide Telescope** WorldWide Telescope (WWT) is another type of model (virtual). WWT is a free astronomy visualization program that lets us explore just about anything in space. Over the next 2 weeks, we will use WWT to learn more about the Earth-Sun system. We will compare how things look from space vs. how things look in the sky from Earth. WWT will help us connect the space-based and earth-based perspectives. Video will show realistic WWT views of • Rotation • Revolution
1f	Day 1 Activity sheets (one per student)	**Activity Sheet** (8 min)	Students work in pairs on Activity Sheet: *Draw a space-based diagram that shows why we have day and night on Earth.*

SESSION 2: The Apparent Path of the Sun in Our Sky (Part 1)

Total Class time: 45-50 minutes

Goals:

- Lay out vocabulary needed to describe the location of the Sun in Our Sky
  - Cardinal Directions
  - Sky Angle
- Predict what the path of the Sun will be "today"
- Predict whether the path of the Sun will be the same or different on other days
- Learn how the Sun appears to move in our sky "today."

Addressing Misconceptions:

- We say "sunrise" and "sunset" and we watch how the sun moves in our sky. Which object is the thing that is actually moving? (EARTH!)
- What is the apparent path of the sun in our sky, and does it change from day to day?
  - Some students are aware that the sun's path changes, but if you challenge them to describe what the sun's path looks like, most students imagine that the sun rises due East, sets due West, and is directly overhead at midday. Today's activity will help them see how the Sun's true path differs from most people's preconceived idea of how the Sun should move.

Materials:

Cardinal Directions signs

Physical Models - 1 set of materials for each pair of students

- Plastic half-dome Suntracker. Pre-write the NESW cardinal directions in Sharpie on all the Suntrackers.
- Lego Vicky to live under the Suntracker
- Set of 4-color dry-erase markers to write on Suntracker
- Clean paper towels for erasing the marks off the Suntrackers

Virtual Model

- Computer to project Day 2 WWT lesson
- Projector
- Speakers

For each student

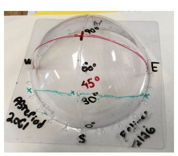
- Day 2-3 Activity Sheets

Classroom Setup:

- Connect computer to projector & speakers
- Link computer to Day 2 WWT lesson
- Tape Cardinal Directions around the room

	Materials Needed	Format	Lesson Outline

2a	Cardinal Directions signs taped around classroom
	
	Day 2 Activity Sheet
		Teacher leads Class Discussion
		(15 min)
		
		Student Partner discussion
		
		Activity Sheet
		(5 min)
			Earth-Based Perspective
			Yesterday we focused mostly on a space-based perspective. Today we will switch to a more familiar, Earth-based perspective.
			
			How would you describe where you see the Sun at different times of day?
			● Consistent terminology:
			    ○ Cardinal Directions – East / West / North / South
			        ■ We've labeled the directions inside our classroom.
			    ○ Horizon
			    ○ Sky Angles
			● Sun "rising" & "setting" as a misnomer because the sun is not actually moving, the earth is.
			
			Think on your own: Can you imagine what is the path of the Sun in our sky today?
			● Where was the Sun at sunrise this morning?
			● Where is the Sun at midday?
			● Where will the Sun be at sunset?
			● Can you point to those places and connect the path that the Sun traces out between them?
			
			Talk to your partner: Does your partner agree with you? Why/why not?
			
			Day 2 Activity Sheet: *On other days of the year, do you think the Sun's path in the sky will be the same as the path you predicted for today, or different? If you think it will be different, how will it be different?*

2b	 Pass out: - Suntracker (one for each pair of students)	WWT on projector	WorldWide Telescope: Suntracker Set-up ● Now let's add another model that can help us be more specific about describing the Sun's location as it appears to viewers on Earth (like us). ● Astronomers sometimes think of the sky as a large half-dome over our location on Earth (like a planetarium). ● Introduce Lego Vicky & Suntrackers (Earth-based perspective) ● Suntracker setup – follow along with WWT

	-Lego person to be "observer" -Dry erase markers (set per pair) -tissue or paper towel to wipe Suntrackers after	Students set up Suntracker model in pairs (8 min)	○ Cardinal Directions - students make sure Suntracker is labeled NSEW and have Lego person face south ○ Horizon - students identify where horizon line is on Suntracker ○ Directly Overhead (90) - label in black marker ○ Sky Angles (30/60/45) – label in black marker NOTE: Mark your sky angles on the SOUTH side of your Sun Tracker
2c		Students work at Suntracker model in pairs (5 minutes)	**Prediction:** What does Lego Vicky see as the path of the Sun through her "sky"? ● Use RED marker. ● Draw an X on Suntracker where you think the Sun was when it rose **today** in Vicky's sky. ● Draw an X where you think the Sun is at midday. ● Draw an X where you think the Sun will be at sunset ● Connect the 3 X's to show the path you think Vicky would see the Sun moving in across her sky *Instructor should walk around and observe what students' predictions look like. If anyone does something noteworthy (different than a path that goes directly overhead from East to West), ask a few students to share their predictions.*
2d		WWT Video Lesson from WWT via projector (10 min) **Students mark Suntrackers**	**Reminder: Do NOT erase predicted path.** You will need to compare the predicted and observed paths. **Observe in WorldWide Telescope:** The apparent path of the Sun in our sky for "today." (September 21) Use WWT to see how we did with describing the Sun's path on the sky. Show Sunpath from Fenway on September 21. Let's just watch it first, then we can mark our Suntrackers. ● Is the Sun due East when it is rising on this day? ● Highest point of path. What sky angle is the Sun at when it is at its highest point? ● Is the Sun due West when it is setting on this day? Ok, let's mark our Suntrackers now. ● Sunrise – Mark location with an X with a black marker. (remember that WWT uses a 10 degree grid, but the sun trackers have 15 degree tick marks. ● Midday – what sky angle is Sun at? Which cardinal direction? *(SOUTH)* Mark with an X. ● Sunset – Mark location with an X. ● Connect those points to show the Sun's apparent path in our sky on May 11.

	Paper Towels	-**Class discussion** **-Students erase Suntracker**	Reflect: ● In what ways was the Sun's actual path on September 21 different from your predicted path? In what ways was the Sun's actual path the same as your predicted path? **Please erase all marks on Suntracker, so they are clean for the next class!**

SESSION 3: The Apparent Path of the Sun in Our Sky (Part 2)

Total Class time: 45-50 minutes

Goals:

- "Observe" and compare how the Sun appears to move in our sky on June 21, Sept 21, Dec 21, and Mar 21.

Addressing Misconceptions:

- Where does the Sun rise and set? (Many people assume the Sun rises due East or due West every day. Students will see that the rise/set locations change depending on time of year and contribute to the Sun traveling a longer path in the sky in the summer vs. winter.)
- Many students think the sun is "directly overhead" every day at midday. Today's activity will help students understand how the highest point the sun reaches in the sky in Boston depends on the time of year.

Materials:

Physical Models - 1 set of materials for each pair of students

- Plastic half-dome Suntracker. In order to save class time, you can pre-write the 30, 45, 60, 90 degree sky angles on all the Suntrackers, so the students don't have to do it in class. If you write the numbers on the inside (backwards), they won't wipe off. (If you have enough Suntrackers to make 2 complete sets, you can keep a separate "Day 3" set with the marks done in Sharpie).
- Lego Vicky to live under the Suntracker
- Set of 4-color dry-erase markers to write on Suntracker
- Clean paper towels for erasing the marks off the Suntrackers

Virtual Model

- Computer to project **Day 3** WWT lesson
- Projector
- Speakers

For each student

- Day 2-3 Activity Sheets

Classroom Setup:

- Connect computer to projector & speakers
- Link computer to **Day 3** WWT lesson

3a		**Teacher leads discussion** (5 min)	Yesterday you made a prediction about the path that the sun appears to travel to a viewer on Earth. You also made a prediction about whether other days will be the same or different. Who said yesterday they think they will be the same? Who thinks they will be different? Let's test our our predictions using WWT.
3b	Pass out: -Suntrackers -Dry Erase markers -Sticky Vicky (Lego person) -Paper towels to erase Suntrackers Ask students to take out Activity Sheets from yesterday.	**Instructor review Suntracker** **Activity Sheet** **Instructor projects WWT views** **Students record data on Suntracker** (7 min)	Look at paths of Sun on different days in WWT and mark them on your Suntracker, like we did in the last class for September 21. **Set up Suntrackers** ● Use sun trackers that already have cardinal directions & sun angles marked. ● On teacher's sun tracker only, review what September 21 looked like ○ Rose East ○ Reached 48 degrees at midday along SOUTH side of tracker ○ Set West ● Enter data into Activity Sheet Table **PREDICT**: Who thinks the Sun's path will be different on December 21? Who thinks it will be the same? **WWT: COLLECT DATA (on Suntrackers)** ● **Winter** Path - Dec 21. Use Blue marker ● As you watch, note where the sun comes up, where it is at its highest point, and where it is when sun goes down. ● (Via projector) We'll go through WWT tour of Sun path for each season together. For each, mark the following on your Suntracker: ○ Sunrise: ■ Is the Sun due East when it is rising on this day? ■ Which direction is the Sun in relative to East? ● **TIP:** Look at view on screen. Is the Sun to the right or to the left of East? Now think about Lego person's view **inside** Sun tracker. Have Lego person look East. Should the Sun be rising to the right or to the left of East (if you

		Activity Sheet **Discussion** (8 min) [Instructor projects June Playposit video] **Mark Suntracker**	are INSIDE the sun tracker.) Is that toward North or toward South? (Consider LEGO person's point of view, not yours.) ■ How many degrees away from East? ● **TIP**: Tick marks on the screen in WWT are 10 degrees each. Tick marks on the Suntracker are 15 degrees each. **If the Sun is 30 degrees south of east, that corresponds to 2 tickmarks on the Suntracker.** ■ Mark with an X with correct colored marker. ○ Midday: ■ Which cardinal direction is the Sun in? *(south)* What sky angle is the Sun at? ■ Mark with an X. ○ Sunset: ■ What time? Which direction relative to West? ● (See same tips for Sunrise) ■ Mark with an X. ○ Connect all points to show the Sun's path during each season ■ *Teacher should walk around and check that students have marked Suntrackers correctly.* ○ Fill out **Table on Activity sheet** ■ Sun angle at midday in degrees ■ Length of day in hours ● **Summer** path - June 21. Use Red marker ○ Before we watch WWT, predict: ■ Where will the Sun rise? East/South of East/North of East? ■ How high will the Sun go? Predict the Sun angle at midday. ■ Where will the Sun set? West/South of West/North of West? ■ Do you think there will be more hours of daylight than darkness, the same, or more hours of darkness than daylight? ○ Show June WWT video ○ Sunrise: ■ Is the Sun due East when it is rising on this day? ■ Which direction is the Sun in relative to East? ■ How many degrees away from East? ■ Mark with an X with correct colored marker. ○ Midday: ■ Which cardinal direction is the Sun in? *(south)* What sky angle is the Sun at?

- Mark with an X.
- Sunset:
  - What time? Which direction relative to West?
    - (See same tips for Sunrise)
  - Mark with an X.

Activity Sheet

- Connect all points to show the Sun's path during each season
  - *Teacher should walk around and check that students have marked Suntrackers correctly.*

Discussion

- Fill out **Table on Activity sheet**
  - Sun angle at midday in degrees
  - Length of day in hours

Instructor projects March Playposit video

- Discuss as a class - the spring path will match one of the 3 paths we've already drawn. Ask students to vote which one they think it is. Summer, Fall, or Winter path.

Mark Suntracker

- Show **Spring** path - March 21. Use Green marker
  - Watch video & mark Suntracker as you go.
    - Where is the sunrise?
      - Mark with an X with correct colored marker.
    - Midday:
      - Which cardinal direction is the Sun in? *(south)* What sky angle is the Sun at?
      - Mark with an X.
    - Sunset:
      - What time? Which direction relative to West?
      - Mark with an X.

Activity Sheet

    - Connect all points to show the Sun's path during each season
    - *Teacher should walk around and check that students have marked Suntrackers correctly.*

Discussion

  - Fill out **Table on Activity sheet**
    - Sun angle at midday in degrees
    - Length of day in hours

Discuss: How did your predictions compare to the observed Sun paths?

3c		**Activity Sheet** (10 min) **Erase Suntrackers**	**COMPARE and ANALYZE** ● Answer questions on activity sheet **RECORD Your Ideas** *In what ways do you think the Sun's **height** in the sky and **length of day** affect temperature?* **Please erase all marks on Suntracker, so they are clean for the next class!**

SESSION 4: How Does Sun Angle Affect Temperature On Earth?

Total Class time: 45-50 minutes

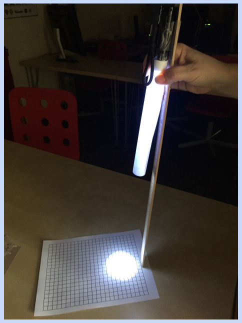
Adapted from the ARIES Curriculum

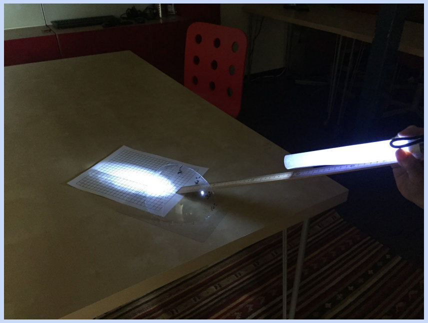
Goals:

- Use a flashlight and grid paper model to measure how the area of ground illuminated by the light source changes depending on the "Sun angle," which impacts intensity of light received at a location on Earth.
- Understand WHY a higher sun angle leads to more intense light, and a lower sun angle leads to less intense light

Addressing Misconceptions:

- *Some students may focus more on the number of squares lit up rather than the brightness of the light at each square. This may lead them to the *incorrect* conclusion that more squares lit => more total amount of light. It may help to use an analogy like, "Pretend each square on the grid has 1 person living on it. The flashlight is like a friend who has $100 to divide among all the people who live where the flashlight is shining. If the flashlight is shining on 4 squares (high sun angle), each person gets $25 (lots of light). If the ray is shining on more squares, say 25 (low Sun angle), each person will only get $4 (very little light).*





Materials:

Physical Models - 1 set of materials for each group of FOUR students

- Protractor or Suntracker cut in half (with angles pre-marked)
- Paper rolled into a tube and taped around flashlight (to keep beam focused on the grid)
- Flashlight+paper tube taped to meter stick at about 50 cm mark (so "distance" from Sun to ground can't change)
- Gridded paper

<table>
<tr><td colspan="4">For each student
● Day 4 Activity Sheets</td></tr>
<tr><td>4a</td><td></td><td>Class Discussion
(8-10 min)</td><td>Review. Over the past 2 days, we saw that apparent path of the sun changes over the course of the year.
● HOW does it change?
○ Highest sun angle reached (at midday) is higher in the summer, lower in the winter
○ The total hours of daylight is more in the summer, less in the winter
● How does this connect with the changing temperatures we experience on Earth (specifically in Boston)? What effect does sun angle have on temperature?

Gather predictions from class:
● Will the intensity / brightness / energy provided by the light change with changes in sun angle?
○ If so, how? (i.e. which sun angles will have more intensity?)
○ If not, explain why.</td></tr>
<tr><td>4b</td><td>Day 4 Activity Sheet

-Paper tube taped around flashlights, taped to meter sticks
-Half Suntrackers or protractors
-Gridded paper</td><td>Hand out supplies and activity sheets (3-5 min)

Students use Suntracker to collect data in groups of 4 (15 min)

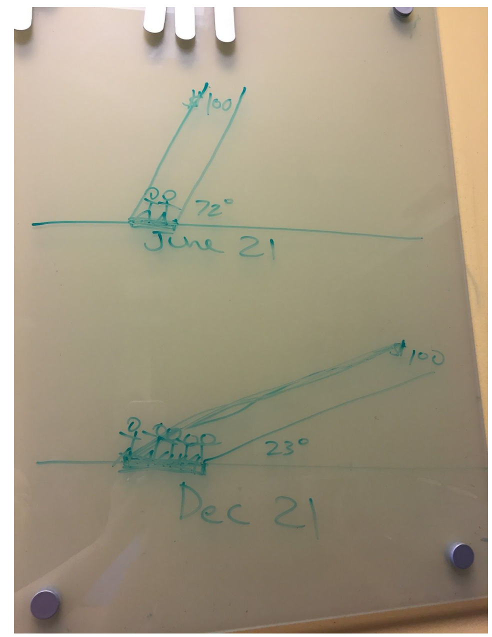
Activity Sheet question in groups (3-5 min)

Individual responses to</td><td>Let's test those predictions with a model:

● Turn off the classroom lights

<u>A. COLLECT DATA (on activity sheet)</u>
● General instructions
○ Hold flashlight at 4 different Sun angles indicated in Activity Sheet table.
■ (Move the sun tracker or protractor out of the way once you have found the correct Sun angle)
○ Use a pencil to draw an outline of the illuminated part of the grid. Label the outline with the Sun angle.
○ Be sure to keep end of meter stick on table, so the distance from the Sun to the ground does NOT change.
● 1 person is responsible for (doesn't have to be the same person for each Sun angle):
○ moving the angle of the flashlight and making sure the protractor or Sun tracker is out of the way once you're at the correct angle..
○ holding the bottom of the flashlight steady, so it doesn't wobble around.
○ drawing and labeling the outline of the area illuminated by the flashlight.
○ recording the number of squares illuminated.

● Turn on the classroom lights once all groups are finished.</td></tr>
</table>

		Activity Sheet (5 min)	● Work together to count the number of squares illuminated by flashlight for each Sun angle. Estimate if some squares are only partially lit. ○ To save time, you can calculate the area of a rectangle inside the lit up area and then add the count of additional squares around the rectangle. ○ NOTE: The values at your table might NOT match numbers at another table. ● Everyone in each group should write down the counted values in their table. ● Determine the fraction of light striking a single square at each Sun angle. For example, if the flashlight illuminated 15 squares, then each square receives 1/15 of the light. **<u>B. COMPARE & ANALYZE:</u>** ● Students complete this section of Activity sheet with their groups **<u>C. RECORD YOUR IDEAS</u>** *Based on what we have learned so far, explain why you think it is warmer in summer than in winter.*
		Class Discussion	**<u>HOW does Sun angle impact temperature?</u>** As a class discuss ideas shared in section C) of Activity Sheet ● At a HIGH sun angle, the light is concentrated over a smaller area. Each patch of ground experiences more intense sunlight. ● At a LOW sun angle, the same amount of light is spread out over a large area. Each patch of ground experiences less intense sunlight. 

SESSION 5: Earth's Tilted Axis and Sun Angle

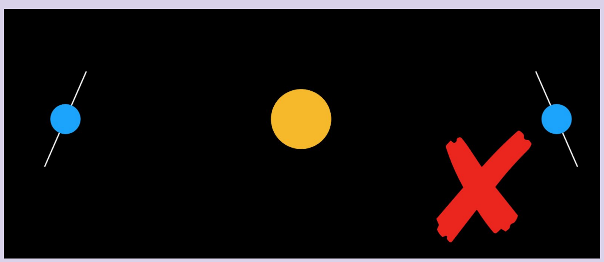
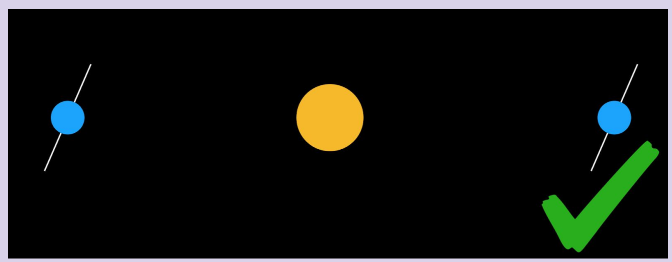
Total Class time: 45-50 minutes

<u>Goals</u>:

- Use virtual and physical models to understand how Earth's rotation axis is tilted. The direction of the tilt is fixed compared to a very distant point in space (Polaris).
- Use globe + Lego person model to understand how Earth's tilted axis leads to higher midday Sun angles in the summer and lower midday Sun angles in the winter.

<u>Addressing Misconceptions</u>:

- When modeling Earth's tilted axis, students have trouble understanding what we mean when we say "the direction of the tilt is fixed compared to a very distant point in space (Polaris)." Students often imagine Polaris as a specific point in the room, for example a sprinkler on the ceiling. The reason this leads to trouble is that Polaris is MUCH farther away than can be modeled in a classroom. If the Earth-Sun distance were scaled down to ~1 meter, at this same scale, Polaris would have to be at a distance of ~27,000 km (which is farther than the distance you would have to travel to get from the North Pole to the South Pole on Earth!) If you imagine Polaris to be inside the classroom (WAY too close), the result of this is that in the student's model, the same hemisphere of the Earth is always tilted toward the Sun as they orbit around the Sun. This diagram shows the incorrect result (compared with the correct result).

- The instructions we give for the model (always tilt your model Earth's northern axis toward a specific wall, rather than at a specific point in the room) is meant to alleviate this issue.

<u>Materials</u>:

Physical Models - 1 set of materials for each group of 4 students

- Stack of books to keep Sun at correct height relative to Earth (roughly just below sternum height when students are standing)
- Seasons "placemat" that students will place on their stack of books

- Yellow sun that students will place in center of their “placemat” (on a ring, to keep it from rolling off)
- Lego Vicky to attach to Earth at Boston to see how the Sun angle changes with time of year.
- A foam Earth speared with a dowel to represent the rotation axis, **without** a Lego person attached
- Another foam Earth speared with a dowel, **with** a Lego person attached

Virtual Model
- Computer to project Day 5 WWT lesson
- Projector
- Speakers

For each student
- Day 5 Activity Sheets

<u>Classroom Setup</u>:
- Print Seasons signs and tape them up in correct order around room. “Winter” should be on a wall with some unique feature (for example, a flag or a whiteboard). The order of the seasons signs should match the order on the “placemats” to be printed for the students. (Earth travels counterclockwise around Sun when viewed from above.)
- Connect computer to projector & speakers
- Link computer to Day 5 WWT lesson

5a		**Class Discussion** (5 min)	Day 2-3 big ideas: ● Sun angle at midday changes – higher in summer, lower in winter ● Longer days/longer sunpath in summer ● Shorter days/shorter sunpath in winter Day 4 big idea: higher sun angle -> light concentrated on smaller area of ground -> more intense sunlight -> warmer temperature Today we will introduce a new component to our model to start thinking about WHY the sun is higher in summer and lower in winter.
5b		**WWT on Projector**	**<u>Earth’s Tilted Axis</u>** Most people have heard that the Earth’s rotation axis is tilted. What does that mean? **<u>Watch WWT:</u>** ● What does it mean that the Earth’s axis is tilted?

<table>
<tr><td></td><td>For each group of 4 students:
- 6” ball to represent Sun
-plastic ring to prevent Sun from rolling off
- Earth ball with dowel rod as axis
- Stack of books to raise Sun
- Seasons “placemats”

- Day 5 Activity Sheets</td><td>(15 min)

Students in pairs explore tabletop model (follow steps on activity sheet)
(15 min)</td><td>● Which direction does the Earth’s axis point in throughout the year?
● How does the tilt look to observers on different sides of the solar system?

<u>Materials:</u>
● Hand out physical model materials - 1 set per group of 4 students
    ○ At first only give students Earth without Lego person attached.
● Hand out Day 5 Activity Sheets - 1 sheet per student

This video for teachers demonstrates what this model should look like when students are doing the activity correctly.
This video for teachers shows common mistakes students make and some tips.

<u>Tabletop model:</u>
● Students should orient the Seasons “Placemat” on top of their stack of books to match the order of the Seasons signs around the room. (The side of the paper that says “Winter” should face the wall that says “Winter,” and so on for the remaining seasons).
● Instructor should mentally note a particular feature of the wall where the “Winter” sign is taped. For example, that wall might have a flag on it.
● Instructor should give an instruction that the Northern axis of Earth must ALWAYS be tilted to face the wall that has the noted feature on it, for example, the FLAG.
    ○ (It is important NOT to say “point the axis toward the winter wall” because that may lead to confusion for students. The axis simply points in a particular direction always, and inside our room, that happens to be the direction of the wall with the flag, which has no real-life analogy in space.)
● Students in the groups will stand around the Sun at 4 sides, each representing the Earth at a different season. They will move the Earth around the Sun, passing it to the next teammate as the Earth approaches the next Season.
● Be sure students know that they are responsible for monitoring how their teammates orient the Earth’s axis as they orbit the Sun. (Students will often start changing the direction of the axis tilt. If they get it wrong, their teammates need to alert them to try again with the correct orientation.)
● Follow instructions on Activity Sheet - students should check boxes as they go.
    ○ Model Earth orbiting over a year, keeping consistent axis tilt.
        ● Once a group demonstrates that they can complete a revolution accurately, switch their Earth to one with a Lego person attached.

    ○ Add day/night component to model at each time of year.</td></tr>
</table>

5c	- Earth ball with dowel rod as axis, with Lego person attached at Massachusetts
	
		Students work in groups at tables
		
		(Teacher may provide a demo if necessary)
		
		(10 minutes)
		
		Activity sheet
		
		Discussion
		(5 min)
			<u>The Tilted Axis and Sun Angle</u>
			● Lego Vicky is our Earth-based observer
			● When it is summer in MA, where does Vicky have to look to see the Sun at midday?
			    ○ Which way should Vicky be facing to experience midday?
			        ■ *(Her side of Earth should be pointing toward the Sun.)*
			        ■ Turn Earth the right way and be sure to check that the axis tilt is still correct.
			    ○ *(To see sun at midday in summer, Vicky has to bend her neck back and look up at lot, but not quite overhead. Maybe about 70 degrees.)*
			    ○ Point one of Vicky's arms in the direction of the Sun to make a summer "measurement."
			● Move the Earth to the opposite side of the Sun to get to winter.
			    ○ Remember to make sure axis orientation is correct.
			    ○ Where does Vicky have to look to see the Sun at midday in winter?
			        ■ Make sure Vicky is experiencing midday! (When you go around to the opposite side of the Sun, Vicky may end up on the nighttime side of Earth. REMEMBER that the earth is always spinning on its axis making night and day over 180 times between summer and winter!)
			    ○ *(To see sun at midday in winter, Vicky can basically look straight ahead and see the Sun, maybe about 30 degree sky angle)*
			    ○ Point Vicky's other arm in the direction of the Sun to make a winter "measurement."
			
			<u>Observe from the Model</u>
			● Answer Activity Sheet Questions
			
			<u>Reflect/Discuss in pairs</u>:
			● Based on the model, how did Vicky's midday Sun angle change in the summer vs. the winter?
			● Why do you think the midday Sun angle changed?

SESSION 6: Sun Angle and Your Location on Earth

Total Class time: 45-50 minutes

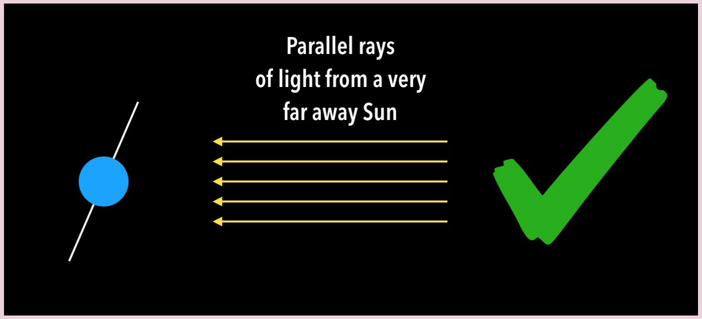
<u>Goals:</u>

- Use globe + Lego person model to reinforce how Earth's tilted axis leads to higher midday Sun angles in the summer (and therefore more intense light and higher temperatures), and lower midday Sun angles in the winter (and therefore less intense light and lower temperatures).
- Learn how to interpret 2-dimensional side-view diagrams of the tilted Earth and determine what season is being depicted.

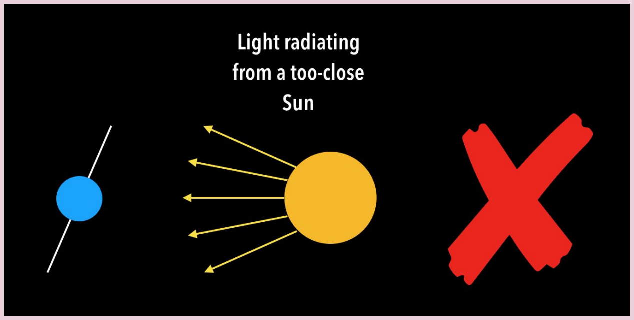
Addressing Misconceptions:

- Because the Sun is so very far away from the Earth, sunlight comes toward Earth in parallel rays. Students often draw the Sun too close, with the rays radiating outward from a circle, which does not allow students to correctly interpret sun angles at different latitudes on Earth.

Correct

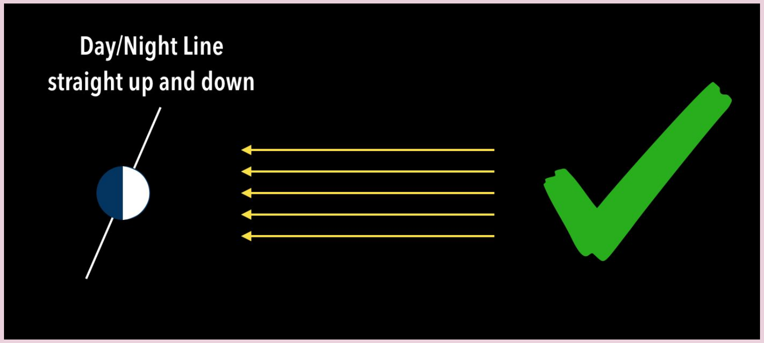


Incorrect

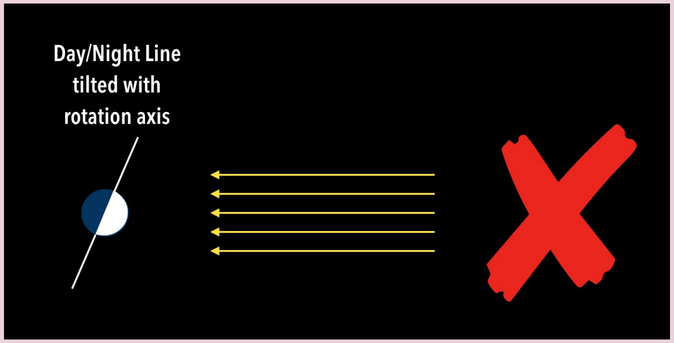


- The day/night line (terminator) on Earth is straight up and down (NOT tilted along with the Earth's axis.) This is absolutely critical for students to get right in order to understand the Day 7 content about why length of day changes from season to season, but we ask them to shade their diagram on Day 6, so we should be sure they do it correctly. This would make a good "Do Now" activity, where students critique the diagrams and figure out which one is wrong and why (if you crop out the green check mark and red x).

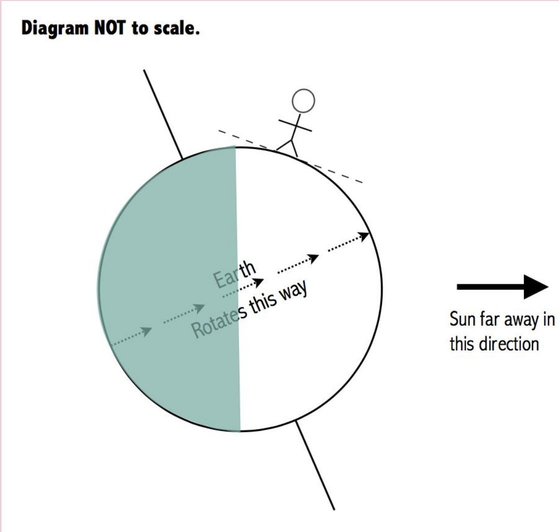
Correct



Incorrect



- Interpreting time of day in a side-view Earth diagram: Some students see that the person depicted is close to the Day/Night line, so they incorrectly interpret time of day as "evening." Around timestamp 3:00 on video 6b, we show the Earth in WWT from this side view, then rotate to a view of the entire day-time side of the Earth, to help students see that the person/red dot in that view is in the middle of the day-time side of Earth. It is **MIDDAY**. This misconception should be addressed when that segment is shown in this lesson.



<u>Materials</u>:

Physical Models - 1 set for teacher to review and demonstrate

- Foam Earth speared with a dowel to represent the rotation axis
- Lego Vicky to attach to Earth at Boston to see how the Sun angle changes with time of year.

Virtual Model

- Computer to project Day 6 WWT lesson
- Projector
- Speakers

For each student

- Day 6 Activity Sheets
- Some Day 6 Bonus sheets if students finish early

<u>Classroom Setup</u>:

- Connect computer to projector & speakers
- Link computer to Day 6 WWT lesson

<table>
<tr>
<td>6a</td>
<td></td>
<td>Class Discussion
Sticky Vicky model recap
(5 min)</td>
<td>Review of Day 5 models:
● Put Sun in middle or room. Have a volunteer show:
○ How does Earth go around the Sun? (Be sure to keep axis tilted correctly)
● New volunteer:
○ How is Earth oriented for summer in MA?
○ Vicky in MA - what sun angle does she see? High or Low?
○ Put Suntracker over Vicky’s head to show connection midday summer sun view (South).
● New volunteer:
○ How is Earth oriented for winter in MA?
○ Vicky in MA - what sun angle does she see? High or Low?
○ Put Suntracker over Vicky’s head to show midday winter sun (South).</td>
</tr>
<tr>
<td></td>
<td>Day 6 Activity Sheet</td>
<td>WWT How Sunlight Travels
(5 min)

Activity Sheet
Students can work in pairs
(5 min)

Continue WWT Video
(5 min)</td>
<td>Show WorldWide Telescope: How Sunlight Travels
● This parallel beam representation is important for students to learn how to interpret sun angle (based on where the viewer is located on Earth).

● Hand out Activity Sheets
○ Answer first 3 questions (up through “Sketch in several rays from the Sun, to show how you think Sunlight reaches the Earth”)

Goal of this sequence is to help students learn to interpret these 2D side-view diagrams of Earth (which appear frequently on standardized assessments).

● Activity sheet diagram
○ Views show how the activity sheet diagram matches up with what they see in WWT.
■ WWT video will guide students through these steps as the questions appear on screen:
● How does the diagram compare with the real Earth?
● What do the straight lines represent? (rotation axis)
● What do the arrows tell you? (rotation direction/equator)
● What does Sun far away in this direction mean?
● Who does stick figure represent?
● Significance of Not to Scale
● Time of Day for Vicky</td>
</tr>
</table>

		Students work on Activity Sheet in pairs (~7-8 min)	• *Representation of Vicky's ground* WWT will pause at appropriate points and tell students when to continue completing Day 6 Activity Sheet **Page 1** - Work with partner to complete.
6c		**Continue WWT** Students work on **Activity Sheet** in pairs (7-8 min)	Return to WWT Update responses to pg 1 questions as needed and have students answer Page 2 as prompted by WWT. Students can work on bonus questions if they finish early.

6d		**Class Discussion** (5 min)	Recap:
			• Q. "WHY does the summer have a high sun angle and winter a low sun angle?"
			  ○ A. Summer: your hemisphere is tilted TOWARD sun. This tilted axis lowers your position relative to the Sun, so the Sun looks high.
			  ○ A. Winter: your hemisphere is tilted AWAY from sun. This tilted axis raises your position relative to the Sun, so the Sun looks low.

SESSION 7: Students explore hours of daylight in WWT software

Total Class time: 45-50 minutes

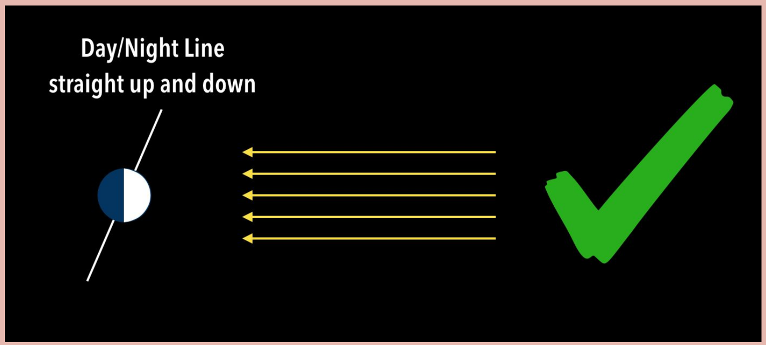
Goals:

- Use virtual and physical models to understand how the Earth's tilted axis affects length of day at different times of year
- Make virtual "observations," collect data, and compare of number of of day/night hours experienced at different locations on Earth using the virtual, computer (WWT) model

Addressing Misconceptions:

- Distinguishing the AXIS vs. the Terminator line. Half of Earth is always lit, but from a side perspective this is a vertical divide; **not** along the axis of rotation. (Note that if the day/night line were aligned with the rotation axis, there would always be 12 hours of daylight and night time all year long.)

Correct



Incorrect

- Students may recognize that there are 24 total hours in one Earth rotation, but often think that there are always 12 hours daylight and 12 hours of darkness. Using the virtual (WWT) model, students will observe locations on Earth that spend very different amounts of time in daylight/darkness relative to the N&S poles. Guide students in connecting that when the location (one's latitude) is closer to equator, there is less of a change in the number of hours daylight as compared to a location more proximate to N & S poles (like Boston).

- Students sometimes fail to see length of day as an its own mechanism for impacting Seasons that is independent of sun angle and intensity of light.
    - Cookie baking analogy can help students see how the two things (sunlight intensity; hours of daylight) independently impact seasons
        - Sun angle -> affects temperature of the oven. Imagine baking cookies at 250 degrees (winter sun angle intensity) vs 450 degrees (summer sun angle intensity)
        - Hours of daylight -> how long cookies are in oven. Imagine baking cookies for 9 minutes (shorter winter days) vs 15 minutes (longer summer days)

<u>Materials</u>:

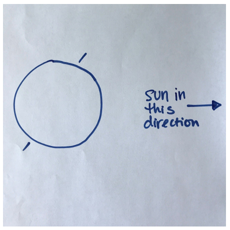
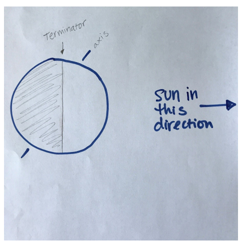
Physical Models -
- Sticky Vicky on Earth Globe (for review segment)

Virtual Models -
- Computer to project introductory Day 7 WWT lesson
- One laptop or chromebook per pair (or trio) of students to WorldWide telescope
- Link to Day 7 tour should be in an easy to access location

For each student -
- [Day 7 Activity Sheets]

Classroom Setup -

- Connect computer to projector & speakers
- Link computer to Day 7 WWT lesson
- Have chromebooks/laptops ready for distribution to each pair of students for 7c

7a	On whiteboard  	**Class discussion** (7-8 min)	**<u>Review the connection from earlier discussions:</u>** ● Ask students to consider all the different components involved in our experiences of the seasons here in MA. What things have we determined make a difference so far? ○ *How high or low the Sun is (Sun angle), tilt of the Earth's axis with regard to the Sun's location. There are more hours of daylight in the summer than the winter.* ● Why are there more hours of daylight in summer than in winter? Who has an idea? ○ *(gather student ideas, but don't need to share correct answer yet).* ● Draw the diagram at left on the whiteboard, have one student shade in the half lit/half dark ● Intro/review the vocabulary: **Terminator** - Astronomers use this term to distinguish the line that divides the half of the Earth by daylight and darkness ○ *Reinforce the idea that the terminator line is NOT aligned with the tilt of Earth's Axis*
7b		**WWT on projector** (15 min)	How does tilted axis make the daytime longer in the summer than the winter? ● WWT visualization about how tilted earth makes length of day longer in summer/shorter in winter. ● At each pause point, ask students to discuss what they think the answer is and make choices together as a class. They can vote anonymously by placing the correct number of fingers under their chin. (1 for the first choice, 2 for the 2nd, etc).
7c	Activity Sheet Day 7 Laptops with WWT tour loaded or Chromebooks with link to WWT tour	**WWT** in **pairs on computers** (15 min)	WorldWide Telescope + Activity Sheet Day 7: Tilt & Day length *If using WWTA computers:* *Before allowing students to log in to computers, explain the following to minimize chances of computers getting into weird states:* ● *In upper right hand corner of screen, look for blue globe icon that says "Seasons Day 7"* ● *Double click the icon **ONCE**.*

			• *WAIT patiently. WWT sometimes takes a long time to load. If students keep double clicking, it is more likely to crash after it does finally open.*
			
			Login for laptops: Select STUDENT or WWTA - password is "wwta"
			
			If using school computers, provide students with the browser link to the Seasons Day 7 tour.
			
			When WWT opens, students will see a screen that says "Activity Sheet Predictions." for June 21.
			• They will see a view of Earth on June 21. Several cities are marked on the globe in different colors.
			
			• On June 21, do you think the total hours of daylight is more or less than in Boston in
			  ○ Barrow, Alaska, 71 degrees North
			  ○ Quito, Ecuador, 0 degrees
			  ○ Puerto Montt, Chile, (41 degrees south)
			  ○ McMurdo Station, Antarctica, 78 degrees south

		Students should manipulate view in WWT to answer questions.	• Students can **left click and drag the mouse** to turn the globe. • They should look at the cities that are experiencing different amounts of daytime and night time on this date.
		Students work on **Activity Sheet** in pairs	Day 7 Activity Sheets • Use the day/night information from the WWT view to answer questions about June 21 on the Activity Sheet. • Once they've finished all the questions, they should click "MOVE ON" • Repeat for Dec 21 & Sept. 21 • Answer Reflection Questions on Activity Sheet.
		Class discussion (7-8 min)	Discussion: • WHY does a tilted axis lead to different amounts of daytime/nighttime at different times of year?

			○ *When the Northern Hemisphere is tilted towards the Sun,the day/night terminator is such that the Northern hemisphere spends more of the 24 hour rotation period on the side of Earth getting direct light from Sun* ○ *The AXIS is not aligned with the terminator line* ● How does having more hours of daylight impact temperature in Boston? How does having a higher sun angle impact temperature in Boston? ○ Cookie baking analogy. ■ Sun angle -> affects temperature of the oven. Imagine baking cookies at 250 degrees (winter sun angle intensity) vs 450 degrees (summer sun angle intensity) ■ Hours of daylight -> how long cookies are in oven. Imagine baking cookies for 9 minutes (shorter winter days) vs 15 minutes (longer summer days)

SESSION 8: Does distance affect Seasons? and Review

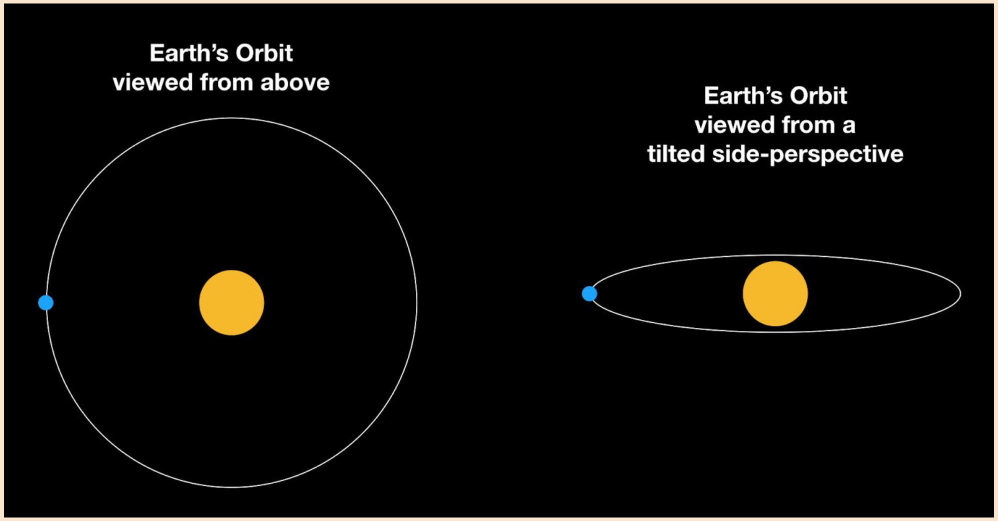
Total Class time: 50-55 minutes

<u>Goals:</u>

- Learn that the shape of the Earth's orbit is very very very close to circular.
  - Recognize that the Earth is NOT closer to the sun in its orbit during the summer than the winter.
- Recognize that the Earth's tilt does NOT move your part of the Earth significantly closer to the Sun in the summer than the winter.
- Recap what DOES cause Seasons - Earth's tilt
  - Higher sun angle in summer -> more intense light; more hours of daylight
  - Lower sun angle in winter -> less intense light; fewer hours of daylight
  - Medium sun angle in fall/spring -> medium light; 12 hours daylight/nighttime on equinoxes

<u>Misconceptions addressed:</u>

- The Earth's orbit is elliptical, but the eccentricity (amount of ellipticity) is so small that it is essentially circular. Why, then, do so many people think the orbit is very elliptical in shape? It has to do with attempts to depict a 3D orbit from a "side" view, on a 2D page:



- Students might not recognize that this is a tilted view, and incorrectly assume that the Earth is very close to the Sun at some times of the year and farther away at others. Some may have been given this incorrect information by elementary school teachers or family members.

- Students who understand correctly that the Earth's orbit is essentially circular frequently have a different misconception about distance. They think that we experience summer because our hemisphere is tilted toward the Sun, making our position "closer" to the Sun. This is technically true, but the distance between the Earth and Sun is so large by comparison, that the comparative distance change is insignificant (3400 km vs. 150,000,000 km!) in affecting the seasonal variation.

<u>Materials</u>:

Virtual Models
- Computer to project Day 8 WWT lesson
- Projector
- Speakers

For each student
- Day 8 Activity Sheet

Classroom Setup
- Connect computer to projector & speakers
- Link computer to Day 8 WWT lesson

8a	Activity Sheet Day 8	Students work on **Activity Sheet** in pairs (7-8 min)	Does Distance Affect Seasons? Day 8 Activity Sheet What shape is Earth's Orbit? ● Students should sketch what they think Earth's orbit around the Sun looks like from OVERHEAD. *(Do NOT prompt or tell them it is circular!)* ● Complete steps A-C on Activity Sheet Predict: Write in Activity Sheet: At what time of year (if any) do you think Earth is closest to the Sun?
8b		**WWT on projector** (7-8 min) Students work on **Activity Sheet** in pairs (7-8 min) **Class Discussion** (5 min)	WorldWide Telescope: Earth's Orbit ● View segment about the shape of Earth's orbit - basically a circle ● Why do so many people think the Earth's orbit is elliptical? (Tilted perspective) ● See Earth-Sun distances at different times of Year Class vote when video pauses: ● What time of year do you think it is when Earth is closest to Sun? ● Surprise! It's Boston's winter time when Earth is closest to Sun. Activity Sheet: ● Fill in distance data in table on pg 1. ● Pg 2: ○ Compare & Analyze ○ Reflection: Do you agree or disagree with this statement: We have seasons because we are closest to the Sun in the summer. Discuss: ● 147,000,000 km vs. 151,000,000 km. ○ Is this a difference that matters? Difference in distance btw Earth winter and Earth summer is < 3%. Does that seem important? ○ NOTE. Distance from the Sun does affect how warm/cold a planet is, but the differences have to be big enough to matter. ■ Mercury is 60,000,000 km from Sun. Is it hotter there or colder there than on Earth? ■ Pluto is 4,000,000,000 km from Sun. Is it hotter there or colder there than on Earth?

8c		Continue WWT **Optional discussion** (5 min) **Class Discussion** (10 min) Hand out key terms sheet for review Students work on **Activity Sheet** in pairs (10 min)	Continue WWT Optional, if time: Does Tilt Affect Distance? ● Tilt in summer brings Boston ~3,400 km closer to sun compared to winter. Compared to the distance between Earth & Sun (~150,000,000 km), does this distance matter? **Summarize Unit:** ● What are the observed seasonal differences during different times of year? ○ Summer - higher midday sun angle, longer days ○ Winter - lower midday sun angle, shorter days ○ Fall/Spring - medium midday sun angle, equal days/night on equinoxes ● What causes the midday Sun angle to change through the year? ○ Earth's tilted axis. ● How does changing the Sun angle impact temperature? ○ Higher sun angle -> more direct/intense sunlight -> warmer temperatures ○ Lower sun angle -> less direct/intense sunlight -> cooler temperatures ● What causes the length of daylight hours to change through the year? ○ Earth's tilted axis Activity Sheet ● Pg 2: Recap Questions (finish for homework if necessary)

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