ThinkSpace | Moon Phases Curriculum

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Overview

This 2-session lesson uses a blend of hands-on models and computer visualizations to help students understand what causes the Moon's phases. The visualizations are presented using WorldWide Telescope (WWT), a free program that aggregates imagery from the world's most powerful telescopes into a seamless view of the night sky, and offers realistic 3-D views of our solar system, galaxy, and cosmos. The WWT media give students an overview of how the Moon, Earth, and Sun move relative to each other. The hands on and WWT-based activities then help students to connect our Earth-based views of the Moon, to space-based views of the Earth-Moon-Sun system. The goal is to help students visualize and describe how the Moon would appear to a viewer on Earth (for example, mostly dark, or half-lit and half-dark), given a particular overhead view of the Earth, Moon, and Sun. Students follow a series of scaffolded activities that walk them through four steps they can take to reliably make this transformation from a space-based overhead view to an Earth-based view of the Moon.

Students will be able to:

- Describe how the Earth rotates on its axis in one day, and revolves around the Sun in one year
- Describe how the Moon revolves around the Earth in about one month
- Describe the relative distances of the Earth and Moon, and recognize that the Sun is much, much farther away
- Describe and demonstrate how the Sun lights up half the Moon (and half of Earth and all other planets/moons).
  - The lit up half of the Moon faces the Sun, the other half of the moon is dark.
- Describe and demonstrate how, when you are on the side of Earth facing the Moon, you see exactly half of the Moon too.
  - The phase you see depends on how much of the lit up half, and how much of the dark half face Earth.
- Explain how the portion of the lit-up half of the Moon that faces Earth changes in a predictable pattern as the Moon orbits the Earth.
- Explain how the Moon's tilted orbit prevents eclipses from happening every month
  - Because the Moon's orbit is tilted slightly, and because the Moon is far away, Earth rarely blocks sunlight from hitting Moon.
- Explain under what circumstances eclipses can occur
  - If the line of orbital nodes points (this is demonstrated with a hula hoop model - "orbital nodes" is not language used with middle school students) toward the Sun, you will get eclipses. This can only happen twice a year.
- Explain the difference between solar and lunar eclipses

Misconceptions addressed:

- How far is the Moon from the Earth? How far are the Earth & Moon from the Sun?
- Does the Earth usually create a shadow on the Moon?

SESSION 1: Earth-Sun-Moon Relationships and Light

Total Class Time: 45-50min

Activity Sheets (for each student) : The Four Steps

Lesson Goals

- Students can explain the difference between rotation and revolution, and can accurately model the various motions of Earth, Moon and Sun.
- Students can accurately describe the timescale for:
  - One rotation of Earth
  - One revolution of the Moon around Earth
  - One revolution of Earth around the Sun
- Students can qualitatively describe the relative distances between Earth, Moon, and Sun.
- Students can identify which part of the Moon or Earth is lit up, based on which side is facing the Sun.
- Students recognize that a half-lit, half-dark Moon will look different from different perspectives. For example, an overhead (space-based) perspective vs. an Earth-based perspective. The Moon's location in its orbit determines what phase an Earth-based observer will see.

Addressing Misconceptions

- Rotation vs. Revolution: focus on the outcome of the movement, rather than trying to memorize definitions for two easily-confused R-words.
  - Which motion causes night and day?
  - Which motion takes a year to complete?
- It's important for students to understand that Earth and the Moon are much, *much* farther apart than what most people assume (because typical depictions of Earth and the Moon are **not to scale**).
- Some students think the Moon produces its own light. And some think the Moon has a fixed light-side and a fixed dark-side, unrelated to the Sun.

Materials

Physical Model

- Lantern or lamp, without a shade (to represent the Sun, placed in the middle of the room)
- Black trash bags or cardboard (to block stray light from the windows)
- Extension cord (if necessary)
- Tape (to secure loose power cords to floor. Gaffer's tape works particularly well. Duct tape is fine too.)
- 6-inch Earth (1 for the classroom)
- 1.5-inch foam moons on a dowel or toothpick (1 per student)

Virtual Model

- Computer to project Session 1 instructional slideshow
- Projector/Screen
- Speakers

Classroom Setup

- Set up lantern or lamp (without a shade) to represent the Sun in the middle of the room.
  - NOTE: The lantern needs to be the only source of light in the room in order for the foam moon and lamp model to work properly. If shades do not adequately darken the room, you may need to tape cardboard or black garbage bags to the windows.
- Tape down any loose power cords on the floor to prevent tripping.
- Connect instructor’s computer to projector/screen and speakers.
- Link instructor computer to Session 1 instructional slideshow.
- Distribute 1 foam moon to every student.

Materials	Format	Day 1 | Lesson Outline
		1.A 15min
	Teacher Leads Class Discussion (5 min)	**Discussion | Understanding Models in Science** 1. Engage students in a **discussion** of what purpose models serve in science • Why do we use models to explore science questions? • What do we need to include in a model to understand the phases of the Moon? < answer: Sun, Earth, Moon > • Why should we include each of these objects? < Sun – because it lights up the Moon and Earth > < Moon – it’s the object we are observing and trying to understand > < Earth – because this object is the place we are looking from > NOTE: Regarding Earth, students will often say, *“It blocks sunlight and makes phases.”* **This is incorrect!** In response, we usually say, *“That is a very common idea, but it is not correct, and we will spend the next few days exploring why.”*

Materials	Physical Model	Modeling | The Distance Scale of Earth and the Moon
- Lantern - 6-inch Earth - Four 1.5-inch foam moons	**Student hands-on**	2. Engage students in a **discussion** of what a scale model is ● Everything in the model has to have the correct proportions relative to their real life counterparts. ○ For example, if your model Moon is a billion times smaller than the real life Moon, the model Earth has to be a billion times smaller than the real life Earth, and the distance between the model Earth & Moon has to be a billion times smaller than the real life distance between the Earth & Moon. ○ Another way of looking at it is that the relative sizes of the objects and the distances between them in the model have to be the same as the relative sizes and distances for the real life objects. 3. Have students **predict** the distance scale ● Hold the 6-inch Earth and a 1.5-inch foam Moon, and explain how they have the correct size scaling. NOTE: The diameter of the actual Earth is 4 times the diameter of the actual Moon. ● Ask a volunteer to hold the 6-inch Earth at the front of the classroom. ● Ask 3-4 volunteers to each hold a foam Moon and stand where they think it should be to represent the correct distance scale from Earth. NOTE: Students usually cluster their foam Moons within ~1–3 feet of the Earth model. Even if they are way off, let them stand wherever they think is right. ● Have all the other students vote on which Moon location is closest to the correct distance scale between Earth and the Moon. NOTE: You'll reveal the correct answer in step 4. 4. Have students **model** the correct distance scale ● Explain that the true distance between Earth and the Moon is 30 times the Earth's diameter. Chances are pretty good that none of the students came close to this distance scale. Since our Earth model is 6 inches, that means the Moon model ought to be 15 feet away (which is typically on the opposite side of a classroom). NOTE: Many classrooms have 12-inch floor tiles. If yours does, you or a student can pace out 15 tiles to measure the correct distance. Otherwise, use a tape measure.

		• Students are usually surprised by how far apart the Moon and Earth actually are (out-of-scale textbook diagrams may have given them the wrong idea). Make sure students understand their original impression is false, and to replace it with this new picture of the model. Understanding this correct distance scale will be really important for modeling activities later (especially when we deal with the full moon).
1.B 10min		
Astronomy Basics (slideshow)	**Slideshow** **on Projector**	**Virtual Modeling | The Earth-Moon-Sun System** 5. Explain that we will now move to **computer models** of the Earth-Moon-Sun system • The computer models are shown in WorldWide Telescope, a program that gives realistic and detailed views of the Earth-Moon-Sun. Present Moon Phases Day 1 Slideshow to the class on a projector. • The first two slides cover two critical (and easily confused) vocabulary terms: **Rotation** and **Revolution**. ○ The emphasis should be placed on the outcomes of the motions (rotation ⟶ day/night; revolution ⟶ year), rather than the exact definitions. NOTE: if you have already gone through the ThinkSpace Seasons curriculum, you can skip these two segments, because you have already watched them. • The third slide, Our Solar System, introduces students to a virtual model of the Solar System, and covers such topics as: ○ What it means to be “to scale” or “not to scale” ○ How Earth revolves around the Sun ○ How the sun lights up Earth to give us day and night • The final slide, How the Sun Lights the Moon, demonstrates how the Sun always lights up half of the Moon (and everything else in the solar system), so all planets and moons experience day and night, just like Earth.

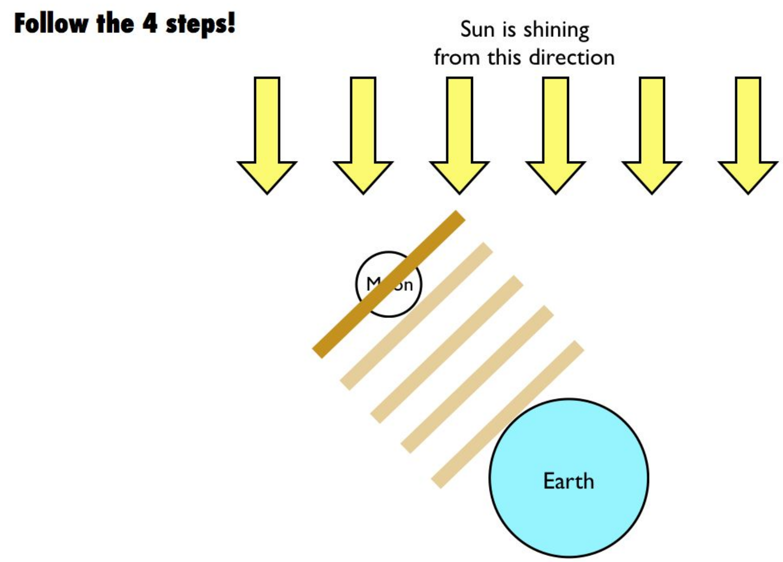
Activity Sheets (one per student)	**Activity Sheet**	**Activity Sheet | Question #1** 6. Students work in pairs to **answer** Question #1 on their Activity Sheets ● Walk around and check student's work. A common incorrect drawing depicts a day/night line that is vertical or horizontal on the page (because that is what they are used to seeing in typical textbook diagrams). Remind them that the lit side of the Moon should align with the direction of the Sun, and should look like this: ● Recap answers as a class and have students correct their work if needed.
	1.C 25min	
Materials - Lantern - 1.5-inch foam moons (one per student)	**Physical Model** **Student hands-on**	**Discussion | How Does the Sun Light Up the Moon?** 7. Begin with a quick **discussion** as a class: ● How is the Moon lit up by the Sun? ● What does the Moon look like from overhead? NOTE: Fix Activity Sheet Question #1 if needed **Modeling | How Do We See the Phases of the Moon?** 8. Have the students **represent** Earth in an Earth-Moon-Sun model ● Give every student a foam Moon. ● Turn on the lantern in the center of the room to represent the Sun. ● Turn off any other lights or light sources in the classroom. ● Have every student stand up, and face the Sun (i.e. the lantern). ● Each student's head represents Earth in its orbit around the Sun. ● Each student's eyes represents an Earth-based observer looking at the Moon. (For example, their eyes represent an observer in America. The back of their head represents Asia). ● Have every student hold their foam moon in their left hand, slightly to the left of the Sun (from their perspective).

9. Prompt students to **think** about their Earth-based perspective
   - If you're on Earth looking at the Moon, what does the Moon look like?
     - How much is lit: all lit / mostly light / half-half / mostly dark / all dark
       < answer: mostly dark – there should just be a sliver of light >
     - What side is lit: lit on the right side / lit on the left side
       < answer : the right side of the Moon >

10. Prompt students to **think** about the space-based, overhead perspective
    - Students should work with a partner. Assign each student the role of Partner 1 or Partner 2.
      - Partner 1 crouches down with their Moon still oriented in front of them and a little to the left of the Sun (they should still see a Crescent Moon lit on the right, as they did in Step 2).
      - Partner 2 pretends they are in a spacecraft way above the Moon and Earth.
        - What does Partner 2 see when they look down over the Moon?
          < answer: They should see a half-lit, half-dark Moon, with the lit up side of the Moon being the half that is facing the Sun. >
        - Optional: What does Partner 2 see when they look down over the Earth?
          < answer: They should see a half-lit, half-dark Earth, with the lit up side of Earth being the half that faces the Sun (i.e. the same as the Moon) >
      - Partner 1 and Partner 2 switch roles so both partners observe the space-based, overhead perspective.
    - Each student should now model a complete Moon Cycle. Give every student a foam moon. No need for partners.
      - Students should hold the Moon in their left hand and move their left arm around in a circle going to their left.
      - Each student starts at the New Moon, continues into a Waxing Moon, through to the Full Moon. Then they continue through a Waning Moon and back to the New Moon.
        NOTE: The Moon orbits counterclockwise if you are looking down from above the North Pole. Make sure students are revolving their foam moons in the correct direction.
        NOTE: Students should keep their head facing the Moon as they recreate the Moon

		Cycle. Remind them that Earth will actually rotate on its axis 29 times during the 29-day Moon Cycle. ○ Ask students to observe how we see more and more of the lit up side as the Moon moves from the New Moon position to the Full Moon position. This is called waxing. ○ Ask students to observe how we see less and less of the lit up side as the Moon moves from the Full Moon position back to New. This is called waning. NOTE: Some students might notice that they won't see a Full Moon using this model unless they hold their Moon high above their heads. This is an important point, and will make much more sense if they remember the true distance-scale of the Moon and Earth, and if they know that the Moon's orbit is actually tilted by 5°.
	Teacher Leads Class Discussion (with whiteboard) & **Activity Sheet**	**Recap | Why Do We See Changing Phases from Earth?** 11. Engage the students in a class **discussion** of the major points of the days lesson. ● Recap at the board: *"Let's talk about **why** we see different phases of the Moon depending on where it is in its orbit around Earth."* ● Here's the major goal: ○ Given the Moon in any location around the Earth, you should always be able to use models (and eventually just a diagram), to figure out what it will look like to someone on Earth. ● Here's the process for figuring out what the Moon will look like from Earth: ○ Model the process at board using the diagram from Question #2 in the Activity Sheet, and have students follow along on their Activity Sheets. 1. Which side of the Moon is lit? < answer: The side facing the Sun. Have students shade in the dark half of the Moon with their pencil >

2. Which side of the Moon is facing Earth?
   < answer: (see diagram below) Start with the ruler representing the observer's ground. Slide the ruler from the ground to the Moon until you have divided the Moon in half. Draw a line across the Moon where the ruler was. The half closest to Earth is the half that faces Earth. >
   NOTE: This concept can be hard for students to grasp. They have multiple misconceptions about which half of the Moon is visible to Earth. Go through the ruler process slowly, and confirm that students are able to recreate this concept themselves.



3. How much of the lit side of the Moon is facing Earth?
   < answer: only a little bit of the lit up side is facing Earth. Most of the side facing Earth is dark. >
4. Do you see the light on the left or right side of the Moon?
   < answer: Sunlight is on the right. >

- *"We will spend tomorrow practicing these 4 steps."*

SESSION 2: Predicting the Phases of the Moon

Total Class Time: 45-50min

Activity Sheets (for each student) : The Missions

Lesson Goals

- Given an Earth-Sun-Moon configuration, students can predict what phase an Earth-based viewer would see, using the following four-step process to connect space-based and Earth-based perspectives of the Moon's phases:
    1. Figure out which half of the Moon is dark/lit.
    2. Draw a line to divide the Moon into the half that faces the Earth and the half that faces away from the Earth.
    3. Determine whether the side facing Earth is mostly dark, mostly lit, etc.
    4. Determine whether the lit-up side of the Moon is on the viewer's left or right (if the Moon is lit-up at all, that is).
- Students understand and can explain how the moon revolves around the Earth, and how this causes the phases of the Moon to change over time.

Addressing Misconceptions

- Students often think that phases of the Moon are caused by Earth blocking light from the Sun that would otherwise fall on the Moon's surface (Crescent Moon and New Moon in particular).
    - Reminding students about the correct distance scale of Earth and Moon (i.e. 30 times the diameter of Earth) can help.
    - Understanding the 5° tilt of the Moon's orbit can also help.

Materials

Physical Model

- Lantern or lamp, without a shade (to represent the Sun, placed in the middle of the room)
- Black trash bags or cardboard (to block stray light from the windows)
- Extension cord (if necessary)
- Tape (to secure loose power cords to floor. Gaffer's tape works particularly well. Duct tape is fine too.)
- 1.5-inch foam moons on a dowel or toothpick (1 per student)

Virtual Model

- Computers for every pair of students
- Headphones for every student
- Splitters (to use multiple headphones with one computer)

Classroom Setup

- Link all computers to Session 2 missions (or provide students with a link from a class website or written on the board to access it themselves).
- Plug one splitter, and a pair of headphones, into every computer.
- Set up lantern or lamp (without a shade) to represent the Sun in the middle of the room.
    - NOTE: The lantern needs to be the only source of light in the room in order for the foam moon and lamp model to work properly. If shades do not adequately darken the room, you may need to tape cardboard or black garbage bags to the windows.
- Distribute one foam moon to every computer setup.

<table>
<tr><th>Materials</th><th>Format</th><th>Session 2 | Lesson Outline</th></tr>
<tr><td colspan="3">2.A 20min</td></tr>
<tr><td>Materials
- Lantern
- 1.5-inch foam moons (one per student)
- Computers (one per pair)
- Headphones (one per student)
- Splitter (one per computer)

Mission 1
(slideshow)

Activity Sheets
(one per student)</td><td>Setup & Instructions

Slideshow
on computers
&
Physical Model
Student hands-on
&
Activity Sheet</td><td>Setup & Instructions | Activity Sheet Missions
1. Get students oriented to begin working through two missions
● Hand out computers, foam moon, Activity Sheets.
● Instruct students to complete activities in WWT in this order:
○ Mission 1
○ Mission 2
○ Moon Cycle

Mission #1 | Predicting Earth-Based Moon Phases
2. Students work in pairs to complete Mission 1 in their Activity Sheet, while simultaneously moving through the Mission 1 sequence in WorldWide Telescope. WWT provides scaffolded, sequential instructions for alternately using the Activity Sheet, the Foam Model, and WWT itself to complete this mission.
● Each pair of students work to determine the correct Earth-based perspective of the Moon from an overhead view of an Earth-Moon-Sun scenario.
NOTE: Mission 1 represents a Waning Crescent Moon.
● "If the Moon is in this location, how do we figure out what the Moon looks like from Earth's Northern Hemisphere?"
● In order to complete this Mission, students will need to:
○ Watch through the steps in WWT.
○ Recreate the orientation of Earth / Moon / Sun using the foam models (with their head as Earth).
○ Ultimately answer the Mission Completion questions (and draw what the Moon looks like) in their Activity Sheet.
○ Select the correct image of the Moon Phase within WWT.</td></tr>
</table>

2.B 10min		
Mission 2 (slideshow)	**Slideshow** **on computers** & **Physical Model** **Student hands-on** & **Activity Sheet**	**Mission #2 | Predicting Earth-Based Perspectives** 3. After completing Mission #1, students continue onto Mission #2. ● WWT asks students to evaluate an Earth-based perspective from an overhead view of a different Earth-Moon-Sun scenario. In this, the second Mission, students are asked to answer the Mission Completion questions (in the Activity Sheet) and select the correct image within WWT, without being provided any Foam Model instructions. 4. Students work in pairs to complete Mission 2 in their Activity Sheet, while simultaneously moving through the Mission 2 sequence in WorldWide Telescope. ● Each pair of students work to determine the correct Earth-based perspective of the Moon from an overhead view of an Earth-Moon-Sun scenario. NOTE: Mission 2 represents a **Waxing Gibbous Moon**. ● *"If the Moon is in this location, how do we figure out what the Moon looks like from Earth's Northern Hemisphere?"* ● In order to complete this Mission, students will need to: ○ Watch through the steps in WWT. ○ Ultimately answer the **Mission Completion** questions (and draw what the Moon looks like) in their Activity Sheet. ○ Select the correct image of the Moon Phase within WWT. ● In this Mission, students are not asked to perform any Foam Model instructions. They must answer the Mission Completion questions and select the correct image within WWT based on their ability to perform the 4 step process.
2.C 10min		
The Lunar Cycle (slideshow)	**Slideshow** **on computers**	**The Lunar Cycle | Understanding the Transition Through Moon Phases** 5. Students **observe** the entire Moon Cycle, from New Moon to New Moon. ● Students watch from an Earth-based perspective, with the option to transition to bird's-eye-view perspectives from above Earth's North Pole at each of eight discrete phases. ● Students are observing and interpreting throughout this Moon Cycle module (i.e. no questions in Activity Sheet).

2.D 10min		
	Activity Sheet	**Activity Sheet | Question #3** 6. Students work in pairs or individually to **answer**: What Causes a Crescent Moon? ● Can be assigned as homework if time is short

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