AmplifyScience

Earth, Moon, and Sun:

An Astrophotographer's Challenge

Investigation Notebook with Article Compilation

These materials are based upon work partially supported by the National Science Foundation under grant numbers DRL-1119584, DRL-1417939, ESI-0242733, ESI-0628272, ESI-0822119. The Federal Government has certain rights in this material. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

These materials are based upon work partially supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A130610 to The Regents of the University of California. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

Developed by the Learning Design Group at the University of California, Berkeley's Lawrence Hall of Science.

Amplify.
55 Washington Street, Suite 800
Brooklyn, NY 11201
1-800-823-1969
www.amplify.com

Earth, Moon, and Sun: An Astrophotographer's Challenge
ISBN: 978-1-64089-870-7
AMP.NA18

Earth, Moon, and Sun:
An Astrophotographer's Challenge

Investigation Notebook

Table of Contents

Table of Contents (continued)

Chapter 3: Lunar Eclipses

Table of Contents (continued)

Table of Contents (continued)

Safety Guidelines for Science Investigations

1. **Follow instructions.** Listen carefully to your teacher's instructions. Ask questions if you don't know what to do.

2. **Don't taste things.** No tasting anything or putting it near your mouth unless your teacher says it is safe to do so.

3. **Smell substances like a chemist.** When you smell a substance, don't put your nose near it. Instead, gently move the air from above the substance to your nose. This is how chemists smell substances.

4. **Protect your eyes.** Wear safety goggles if something wet could splash into your eyes, if powder or dust might get in your eyes, or if something sharp could fly into your eyes.

5. **Protect your hands.** Wear gloves if you are working with materials or chemicals that could irritate your skin.

6. **Keep your hands away from your face.** Do not touch your face, mouth, ears, eyes, or nose while working with chemicals, plants, or animals.

7. **Tell your teacher if you have allergies.** This will keep you safe and comfortable during science class.

8. **Be calm and careful.** Move carefully and slowly around the classroom. Save your outdoor behavior for recess.

9. **Report all spills, accidents, and injuries to your teacher.** Tell your teacher if something spills, if there is an accident, or if someone gets injured.

10. **Avoid anything that could cause a burn.** Allow your teacher to work with hot water or hot equipment.

11. **Wash your hands after class.** Make sure to wash your hands thoroughly with soap and water after handling plants, animals, or science materials.

Name: ______________________ Date: ______________

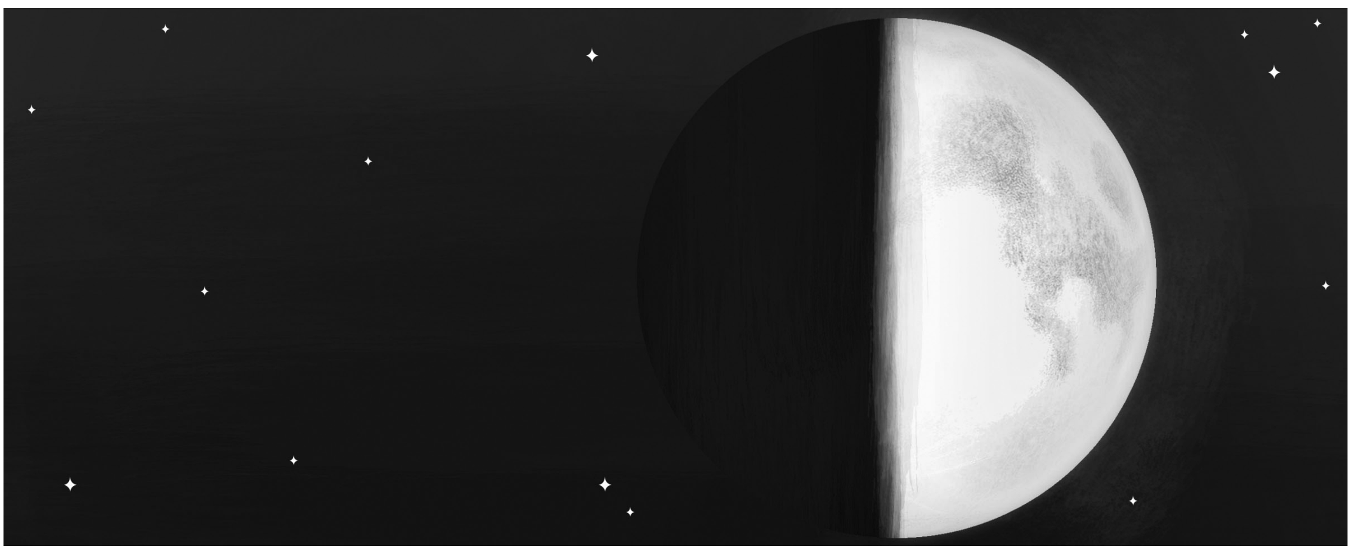
Earth, Moon, and Sun: An Astrophotographer's Challenge
Unit Overview

Have you ever looked at the Moon and wondered why it looks different from night to night? In this unit, you will explore why the Moon's appearance looks the way it does and why it changes. In the role of student astronomer, you will advise Eric Wu, an astrophotographer capturing surface features of the Moon for *About Space* magazine. Through hands-on investigations, Sim missions, and by reading and talking to your peers, you will come to an understanding of the way the Moon moves and why it appears the way it does from Earth.

Name: ______________________________ Date: ______________

Chapter 1: Light and Dark on the Moon
Chapter Overview

In order to take the best pictures of the Moon that he can for *About Space* magazine, Eric Wu needs the light and dark parts of the Moon to look a certain way. To help him find the right time to take these photos, you'll begin by investigating why there is a border between light and dark on the Moon.



Name: ________________________________ Date: ____________________

Lesson 1.2: Picturing the Moon

Welcome to your new unit on Earth, the Moon, and the sun! You are about to take on the role of a student astronomer. Today, you will meet Eric Wu, an astrophotographer trying to take photos of the Moon for *About Space* magazine. Eric is great at taking photos, but he doesn't know much about the Moon. In order to take the best pictures possible, Eric needs the light on the Moon to look a certain way, and he needs you to help him figure out when and why that will happen. You'll begin by using a digital simulation to study light on the Moon. Student astronomers, don't let Eric get left in the dark!

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 1 Question

- Why is there a border between light and dark on the Moon?

Vocabulary

- illuminate
- moon
- sun

Digital Tools

- *Earth, Moon, and Sun* Simulation

Name: ______________________ Date: ______________

Warm-Up

Thinking About the Moon

Look at these images and think about what you know about the Moon. Then, record your thoughts in the space below.

What do you already know about the Moon?

____

____

____

____

____

____

Name: ______________________________ Date: ____________________

Investigating Light on the Moon

Part 1: Introducing the *Earth, Moon, and Sun* Simulation

Talk with your partner as you explore the *Earth, Moon, and Sun* Simulation. Share what you both notice.

As you explore the Sim, discuss the following questions with your partner:

- How many different views are there in the Sim?
- What do the different buttons do in the Sim?
- What did you notice about what you can change in the Sim?
- What questions do you have about the Sim?

Part 2: Using the Sim to Investigate Light on the Moon

Goal: Look for evidence in the Simulation to answer the Investigation Question: *Where does the Moon get its light?*

Tips:

- You may find it helpful to close some views and observe one view at a time.
- You may want to try turning sunlight on and off.

Where does the Moon get its light? (check one)

- ☐ The Moon makes its own light.
- ☐ The Moon gets light from the sun.
- ☐ The Moon gets light from Earth.

What evidence from the Sim helped you answer the Investigation Question?

____

____

____

____

Name: ______________________ Date: ______________

Homework: Reading “The Solar System Is Huge”

Read the “The Solar System Is Huge” article. Annotate anything in the article that helps you understand why it is difficult to make models of objects in the solar system. When you are finished reading, use your annotations to answer the question.

Why is it difficult to make models of objects in the solar system?

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________ Date: ______________

Lesson 1.3: Modeling Light and Dark on the Moon

Eric Wu needs to take pictures at the border between the light and the dark part of the Moon. But, if the sun is so much larger than the Moon and it is what lights up the Moon, then why is part of the Moon dark at all? In this lesson, you will set up a physical model of the Earth, Moon, and sun system to gather evidence about why part of the Moon is dark.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 1 Question

- Why is there a border between light and dark on the Moon?

Key Concepts

- The Moon does not make its own light; the sun illuminates the Moon.

Vocabulary

- illuminate
- model
- moon
- scale
- sun

Digital Tools

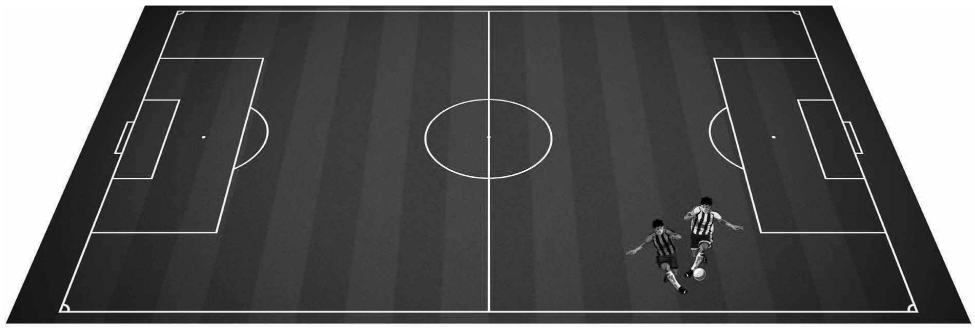
- Scale Tool

Name: ______________________ Date: ______________

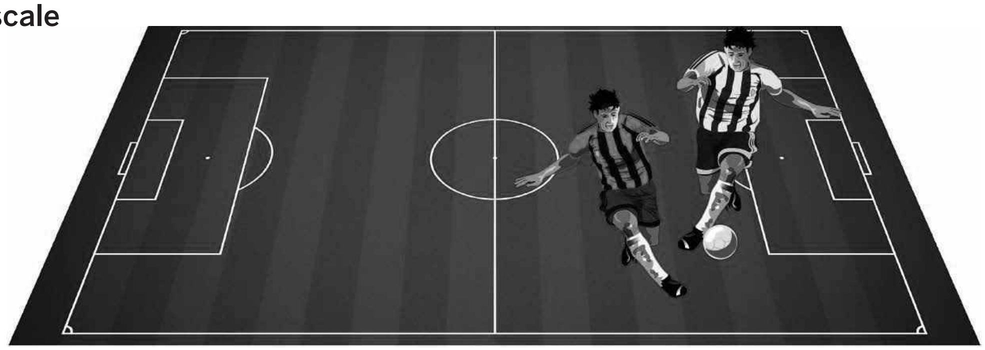
Warm-Up

How useful is the model?

Model 1: to scale



Model 2: not to scale



In which model can you see the ball most clearly? (check one)

- ☐ Model 1
- ☐ Model 2

Which model is more accurate? (check one)

- ☐ Model 1
- ☐ Model 2

Which of the two models do you think is most useful? (check one)

- ☐ Model 1
- ☐ Model 2

Name: ______________________ Date: ______________

Thinking About Scale in the Moon Sphere Model

Discuss these questions with your group.

1. Do you think that the lightbulb and the Moon spheres are "to scale" compared to the real sizes of the sun and the Moon?

2. If a student holds the Moon sphere out in front of her at arm's length, will the distance between the Moon sphere and her head be "to scale"?

3. Why is it sometimes necessary to use a model that is "not to scale"?

Name: ____________________ Date: ____________________

Homework: Reading "The Dark Side of the Moon"

Read the "The Dark Side of the Moon" article. Annotate anything in the article that helps you understand why part of the Moon is dark. When you are finished reading, use your annotations to answer the question.

Why is part of the Moon dark?

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ____________________

Lesson 1.4: Simulating Light and Dark on the Moon

If the sun illuminates the Moon, then why is part of the Moon dark? Today, you'll use the Sim to answer this question and explain why there is a border between light and dark on the Moon. If you're going to help Eric Wu get the pictures he needs for *About Space* magazine, then there's no time to waste! Good luck, student astronomers.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 1 Question

- Why is there a border between light and dark on the Moon?

Key Concepts

- The Moon does not make its own light; the sun illuminates the Moon.
- When a model is "to scale," object sizes and distances are larger or smaller than in the real world but the same relative to one another. Some models need to be "not to scale" to be useful.
- The sun illuminates the half of the Moon that is facing it, and the other half is dark.
- Light from the sun travels in straight lines.

Vocabulary

- illuminate
- model
- moon
- sun

Digital Tools

- *Earth, Moon, and Sun* Modeling Tool activity: Light and Dark
- *Earth, Moon, and Sun* Simulation

Name: ____________________ Date: ____________

Warm-Up

Light and Dark on the Moon

Think about the experiences you have had during this chapter as you answer the Chapter 1 Question below. You will get a chance to revise your answer later in this lesson.

Why is there a border between light and dark on the Moon?

Name: ______________________________ Date: ________________

Investigating Darkness on the Moon

Investigation Question: *Why is part of the Moon dark?*

Launch the *Earth, Moon, and Sun* Simulation, make observations to help answer the Investigation Question, and follow the instructions below.

Use the space below to record your observations from the Sim that help you answer the Investigation Question. Feel free to draw in the space.

My Observations

Why is part of the Moon dark? (check one)

- ☐ Light from the sun only illuminates half of the Moon.
- ☐ Earth's shadow is on half of the Moon.
- ☐ The Moon only makes light on one side.
- ☐ Clouds are blocking half of the Moon's light.
- ☐ The Moon is made up of light and dark rocks.

Explain how your observations help you answer the Investigation Question.

____

____

____

____

Name: ______________________________ Date: ______________

Modeling Light and Dark

Launch the *Earth, Moon, and Sun* Modeling Tool activity: Light and Dark.

Goal: Show light and dark on the Moon.

Do:

- Press the pencil to edit the light in the Top View panel.
- Drag a light shape onto the Moon. Then, rotate the light shape.

Tips:

- The position of the Moon cannot be edited.
- You can add a light shape to Earth, but you do not need to.

When your model is complete, press HAND IN. Write your partner's name here if you had one:

____

Use your model to help you revise or add to your answer to the Chapter 1 Question: *Why is there a border between light and dark on the Moon?*

____

____

____

____

____

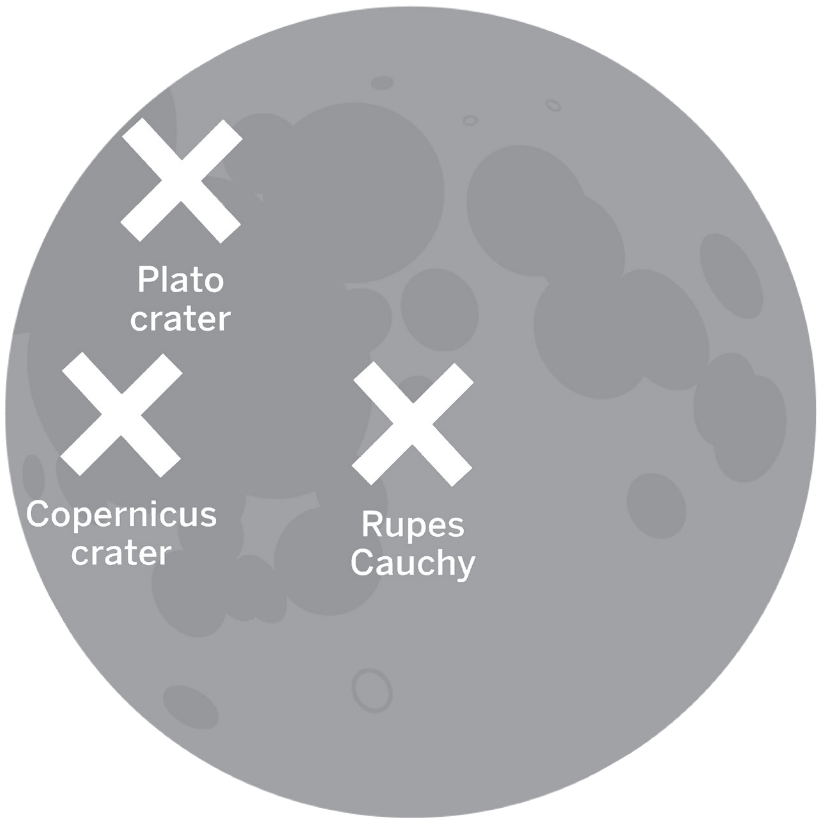
____

Name: ______________________________ Date: ________________

Taking Pictures of the Moon

Look back at the question and the claims about when Eric Wu can take pictures of the three Moon features for *About Space* magazine. With your partner, discuss which claim seems better, based on what you know so far. When you are finished talking, select the claim you think is best below.

Question: When can Eric Wu take pictures of the three Moon features?



Based on what you know so far, which claim do you think is best? (check one)

- ☐ **Claim 1:** Photographs of these features can be taken on any night.
- ☐ **Claim 2:** Photographs of these features can only be taken on some nights.

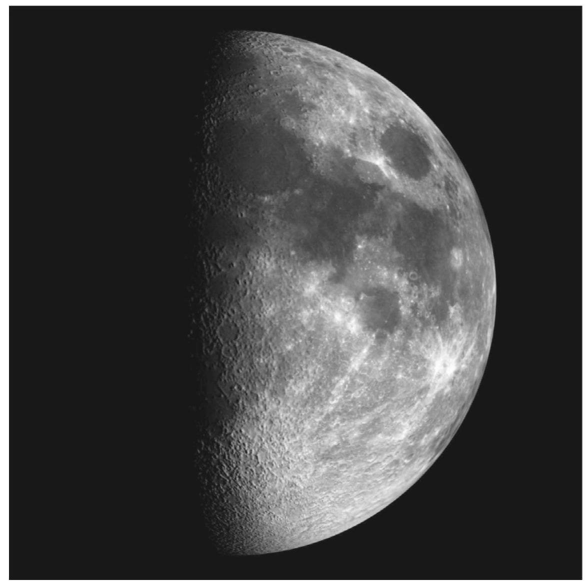
Name: ______________________________ Date: ______________

Homework: Looking Closer at the Moon

As Eric Wu was preparing for his assignment, he found some photos of the Moon that he took a few years ago. He thought that you might be able to use them to help him figure out when he should take the photos for *About Space* magazine. Look at these images and record what you notice. Then, answer the question below.

Image 1

Image 2



What do you notice about these two images?

____

____

____

Why do you think the Moon looks different in these two images? (check one)

- ☐ Because light from the sun is traveling from the **left** in Image 1 and traveling from the **right** in Image 2.
- ☐ Because light from the sun is traveling from the **right** in Image 1 and traveling from the **left** in Image 2.
- ☐ Because light from the sun is traveling in a **straight line** in Image 1, but it is **curving around** in Image 2.
- ☐ Because light from the sun is traveling in a **straight line** in Image 2, but it is **curving around** in Image 1.

Name: ______________________ Date: ______________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. You have been investigating what determines the appearance of the Moon from Earth, in order to tell astrophotographer Eric Wu when he can take photographs. Are you getting closer to understanding what determines the Moon's appearance?

1. I understand where the Moon gets its light. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

2. I understand why we see different phases of the Moon. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

3. I understand what causes the pattern of the Moon's phases. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

Name: ______________________________ Date: ________________

Homework: Check Your Understanding (continued)

4. I understand what happens during a lunar eclipse. (check one)

☐ yes

☐ not yet

Explain your answer choice.

____

____

5. I understand why lunar eclipses happen. (check one)

☐ yes

☐ not yet

____

____

6. What do you still wonder about what determines the Moon's appearance from Earth?

____

____

____

____

____

____

Name: ______________________ Date: ______________

Chapter 2: Moon Phases
Chapter Overview

Even though the sun consistently illuminates half of the Moon, when we look up at the Moon from Earth, it looks very different from night to night. Why does this happen? Will it affect when Eric Wu can take his photographs? Investigating why the appearance of the Moon changes is the next step in helping Eric complete his assignment for *About Space* magazine.

Name: ______________________________ Date: ____________________

Lesson 2.1: "Phases of the Moon"

Okay, student astronomers, you've learned that light from the sun only illuminates half of the Moon, which explains the presence of the terminator, the border between light and dark on the Moon. So why does the Moon look so different from night to night? Some nights, we can see the terminator clearly, and on other nights, it looks like it isn't there at all! If Eric Wu is going to get the pictures he needs for *About Space* magazine, he's going to need you to help him figure out when and why the appearance of the Moon changes. Today, you'll take the next step by reading an article about the many phases of the Moon.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 2 Question

- Why does the border between light and dark on the Moon change location?

Vocabulary

- illuminate
- moon
- moon phase
- orbit
- sun

Name: ______________________________ Date: ________________

Warm-Up

Comparing Photos of the Moon

Eric Wu found a third photo of the Moon that he took a few years ago and sent it to you along with a question. Look at the third image and compare it to the two images Eric already sent you. Then, respond to his question.

Eric said, "I took these photos from the same hill behind my house on three different nights. If half of the Moon is always illuminated and the other half is always dark, then why does the Moon look so different on different nights?"

____

____

____

____

____

____

Name: ____________________ Date: ____________

Reading “Phases of the Moon”

1. Read and annotate the article “Phases of the Moon.”
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

What is something about the text that you discussed with your partner?

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________ Date: ______________

Lesson 2.2: Gathering Evidence About Moon Phases

Student astronomers, you've learned that people have many different ideas about the Moon. As scientists, however, you need to have evidence in order to support a claim. Today, you're going to investigate two claims about why the appearance of the Moon changes. In order to decide which claim is stronger, you'll need evidence from two familiar sources: the Moon Sphere Model and the "Phases of the Moon" article. Which claim will the evidence support? It's time to find out!

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 2 Question

- Why does the border between light and dark on the Moon change location?

Vocabulary

- illuminate
- model
- moon
- moon phase
- sun

Name: ______________________ Date: ______________

Warm-Up

Seeing the Moon in a New Light

Look closely at this image. Then, answer the questions below.

In this photo, what is similar about the appearance of the Moon and the appearance of the stone sphere on the top of the post?

____

____

____

____

Why do you think the appearance of the Moon and the stone sphere is similar in this way?
Hint: Think about the light in the image.

____

____

____

____

Name: ____________________ Date: ____________

Gathering Evidence from a Model

Try to model as many of the five moon phases as you can, using your Moon sphere. As you use your Moon sphere, think about how your model can act as evidence that supports Claim 1 or Claim 2. Discuss this evidence with your partner and record it in the spaces below.

You may not be able to find evidence to support both claims.

Investigation Question: *If half of the Moon is always illuminated, why does its appearance from Earth change?*

Claim 1: The Moon's appearance changes because Earth casts a shadow on the Moon.

Claim 2: The Moon's appearance changes because the position of the Moon changes.

Record your evidence about the Moon's appearance changing because Earth casts a shadow on the Moon.

____

____

____

____

Record your evidence about the Moon's appearance changing because the position of the Moon changes.

____

____

____

____

Name: ______________________________ Date: ________________

Gathering Evidence from a Text

Reread the sections titled "New Moon," "Crescent Moon," and "Quarter Moon" from "Phases of the Moon." As you read, highlight or make note of any evidence in the article that supports Claim 1 or Claim 2. Discuss this evidence with your partner and record it in the spaces below.

You may not be able to find evidence to support both claims in the article.

Investigation Question: *If half of the Moon is always illuminated, why does its appearance from Earth change?*

Claim 1: The Moon's appearance changes because Earth casts a shadow on the Moon.

Claim 2: The Moon's appearance changes because the position of the Moon changes.

Record your evidence about the Moon's appearance changing because Earth casts a shadow on the Moon.

____

____

____

____

Record your evidence about the Moon's appearance changing because the position of the Moon changes.

____

____

____

____

Name: ______________________________ Date: ________________

Choosing a Claim

Discuss with your partner which claim you think is best supported by the evidence you gathered during this lesson. Then, choose the claim that you think is best and explain how your evidence supports this claim.

Investigation Question: *If half of the Moon is always illuminated, why does its appearance from Earth change?* (check one)

- ☐ **Claim 1:** The Moon's appearance changes because Earth casts a shadow on the Moon.
- ☐ **Claim 2:** The Moon's appearance changes because the position of the Moon changes.

Explain in writing how the evidence supports your claim.

____

____

____

____

____

____

Name: ______________________________ Date: ______________

Homework: Reading "Meet a Scientist Who Studies the Early Solar System"

In today's lesson, you used evidence to figure out why the Moon's appearance from Earth changes. To learn about a scientist who uses evidence to figure out how the Moon came to be, read and annotate the "Meet a Scientist Who Studies the Early Solar System" article. Then, answer the questions below.

What kinds of evidence are scientists using to learn about how the Moon came to be?

____

____

____

What excites Kaveh Pahlevan about his work?

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ____________________

Lesson 2.3: Simulating Moon Phases

In order to advise Eric Wu about when he can photograph surface features on the Moon, you need to understand when the terminator will be near those features. You know that the terminator is in different places, depending on the phase of the Moon. Now you will use the Modeling Tool and the Sim to better understand how moon phase and moon position are related. What you learn today will come in handy later, when the time comes to advise Eric.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 2 Question

- Why does the border between light and dark on the Moon change location?

Vocabulary

- illuminate
- model
- moon
- moon phase
- scale
- sun

Digital Tools

- *Earth, Moon, and Sun* Modeling Tool activity: Predict Moon Phase
- *Earth, Moon, and Sun* Simulation

Name: ______________________ Date: ______________

Warm-Up

Exploring New Modeling Tool Features

- Launch the *Earth, Moon, and Sun* Modeling Tool activity: Predict Moon Phase.
- Observe and explore any new features in the Predict Moon Phase activity.

What do you observe that is new and different?

____

____

____

____

What questions do you have?

____

____

____

____

Name: ______________________________ Date: ________________

Modeling Moon Phases

Launch *Earth, Moon, and Sun* Modeling Tool activity: Predict Moon Phase. You will make a model now and have a chance to revise it at the end of this lesson.

When your model is complete, press HAND IN. Write your partner's name here if you had one:

____

Goal: Show how the Moon is illuminated at different times.

Do:

- Tap the pencils to edit the Moon's light in the Top View and View from Earth panels.
- Add and rotate light shapes in the Top View panels.
- Add and rotate a light shape in each View from Earth panel, based on the Moon's position in the Top View panel above it.

Tips:

- In the Top View panels, the Moon is shown in three positions that cannot be edited.
- Need help? Turn on the Guide.
- You can add a light shape to Earth, but you do not need to.

Turn the page to complete the Sim mission, and then return to the Modeling Tool activity to make any revisions from the evidence you gathered in the Sim.

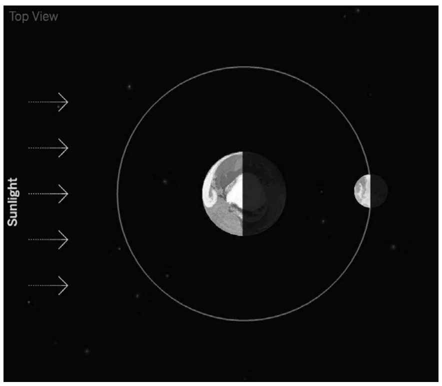
Name: ______________________ Date: ______________

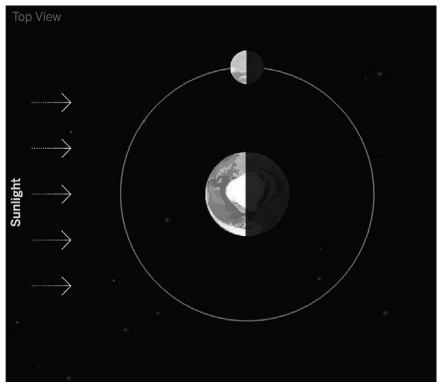
Why We See Phases of the Moon

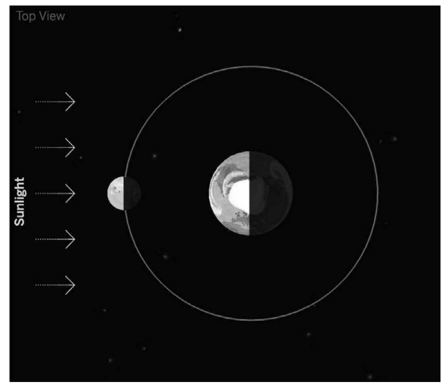
Part 1

Launch the *Earth, Moon, and Sun* Simulation. In Top View, move the Moon to each of the positions shown below. Then, observe the Moon in View from Earth.

Using the words *all, half,* and *none,* record your observations by labeling each of the Top View images below. How much of the illuminated part of the Moon is visible from Earth?







______________ ______________ ______________

Part 2

Launch the *Earth, Moon, and Sun* Simulation.

1. Form partners and choose who will be Partner A and B.
2. **Partner A:** Hide the device from your partner, move the Moon in Top View, observe how much of the Moon is illuminated in View from Earth, and then turn off View from Earth. Show the Sim to your partner, and ask your partner to predict the View from Earth. Then, turn on View from Earth to check that prediction.
3. **Both partners:** Discuss how the position of the Moon around Earth in Top View changes the appearance of the Moon in View from Earth.
4. **Partner B:** Repeat steps 2 and 3 above by quizzing Partner A and discussing.
5. **Both partners:** Try reversing the activity once by turning off Top View and asking your partner to predict the Top View based on the View from Earth.
6. **Both partners:** Continue to take turns quizzing each other and discussing how Top View and View from Earth are related.

Name: ______________________________ Date: ____________________

Lesson 2.4: Moon Phase Patterns

To take photographs of the three Moon features for *About Space* magazine, Eric Wu needs to know in advance where the terminator will be. But how can Eric possibly know that? He can't predict the future! Fortunately, you and your fellow student astronomers are here to help. Today, you will work with the Moon Sphere Model to better understand how the Moon's orbit creates each moon phase, and soon you'll be able to predict the Moon's changing appearance from day to day.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 2 Question

- Why does the border between light and dark on the Moon change location?

Key Concepts

- From Earth we can only see the half of the Moon that is facing us.
- Because the Moon moves to different positions around Earth, we see different amounts of the illuminated half of the Moon. This is why we see different phases of the Moon.

Vocabulary

- illuminate
- model
- moon
- moon phase
- orbit
- pattern
- scale
- sun

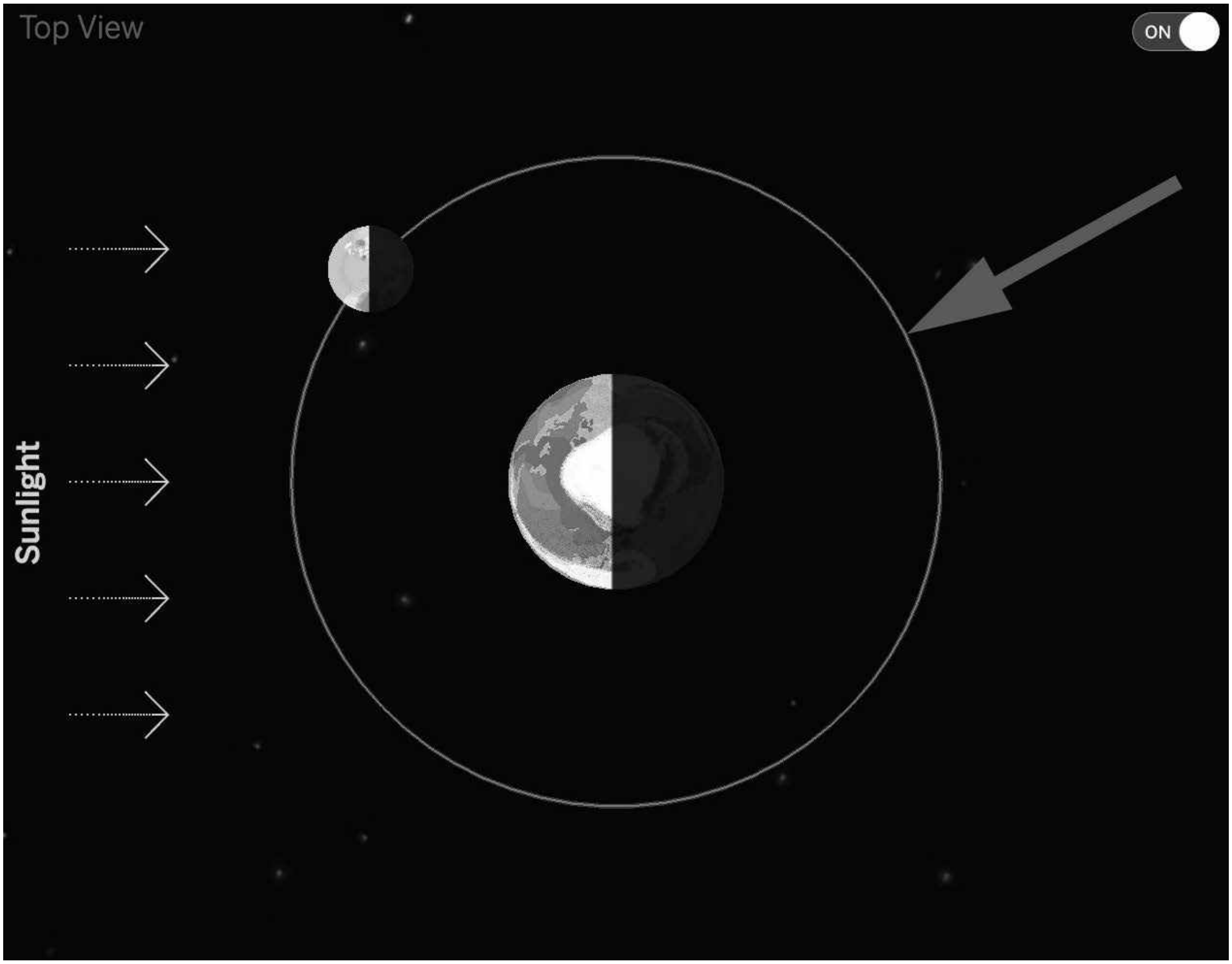
Digital Tools

- *Earth, Moon, and Sun* Modeling Tool activity: Order and Match Views

Name: ____________________ Date: ____________

Warm-Up

Consider the image from the Sim below, and then answer the question.



In this image of Earth and the Moon from the Sim, what does the circle around Earth represent?

____

____

____

Name: ____________________ Date: ____________

The Moon Sphere Model: Phase and Orbit

Observe the Phases of the Moon

- Face the lamp, holding the Moon sphere at arm's length a little above your head.
- Observe new moon phase.
- Turn your body slightly to the left, away from the lamp (sun).
- Observe crescent moon phase.
- Continue turning to observe quarter, gibbous, and full moon phases.
- Continue turning until you observe a new moon phase again.

Work in pairs to observe Top View and View from Earth

- **Top View observer:** Watch from above while your partner moves the Moon sphere in its orbit.
- **View from Earth observer:** Stop periodically, tell the Top View observer what phase you see "from Earth," and have the Top View observer share what the Moon sphere looks like from above.
- Switch roles and repeat.

Name: ______________________ Date: ______________

Write and Share: Discussing Moon Phases

Find the sheet on the next 3 pages that has the number you were assigned (1, 2, or 3). Follow the instructions below to participate in the Write and Share routine.

1. Carefully read and annotate the information you are given.
2. Answer your prompt, using these vocabulary words: *moon, moon phase, orbit, pattern*
3. After everyone in your group has had a chance to write, take turns introducing your prompts and sharing your responses.
4. While one student is presenting, the other two listen carefully.
5. After each student presents, the other students in the group can ask questions or make comments.

Name: ______________________________ Date: ________________

Write and Share: Student 1

Evidence source: “Phases of the Moon” article

> “No matter what phase the Moon is in, one thing is the same: half of the Moon is illuminated by the sun. What changes from night to night is how much of that half we can see from Earth. When the entire illuminated half of the Moon is facing Earth, we see a full circle of light, which we call a full moon. Then, as the Moon continues in its orbit around Earth, we see less and less of it until the illuminated half is facing directly away from Earth, and it seems to disappear. This happens when the illuminated half faces entirely away from Earth, and we call this a new moon. But don’t worry-the Moon is never out of sight for very long. As its orbit around Earth continues, the illuminated half of the Moon moves back into our view-just a little at first, but more and more each night until, about a month after the last full moon, it is finally full again.”

Prompt: How can we predict how the Moon will change appearance from day to day?

Word Bank

moon	moon phase	orbit	pattern

____

____

____

____

____

____

____

____

____

____

____

____

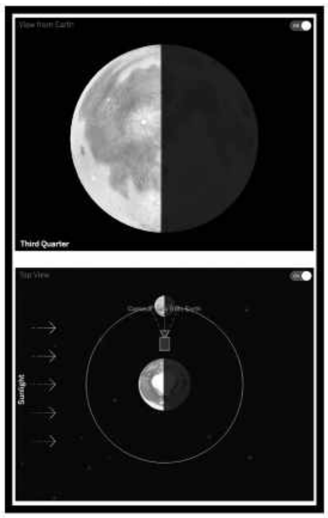
____

Name: ______________________________ Date: ____________________

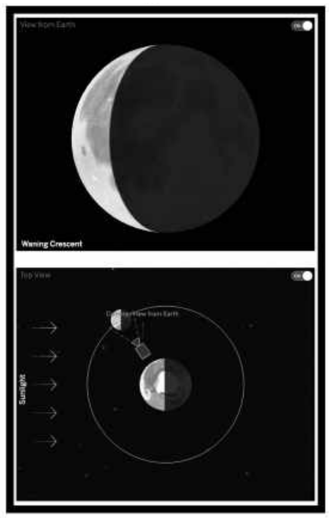
Write and Share: Student 2

Evidence source: *Earth, Moon, Sun* Sim

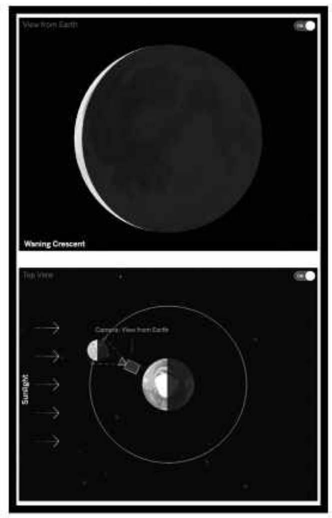
July 18



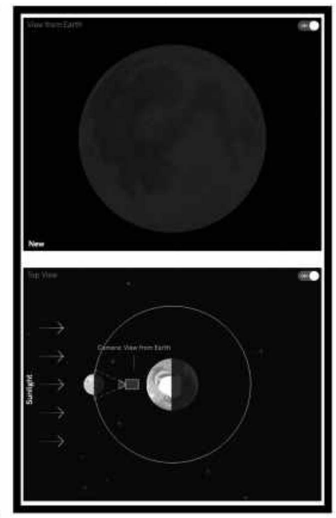
July 20



July 22



July 25



Prompt: How can we predict how the Moon will change appearance from day to day?

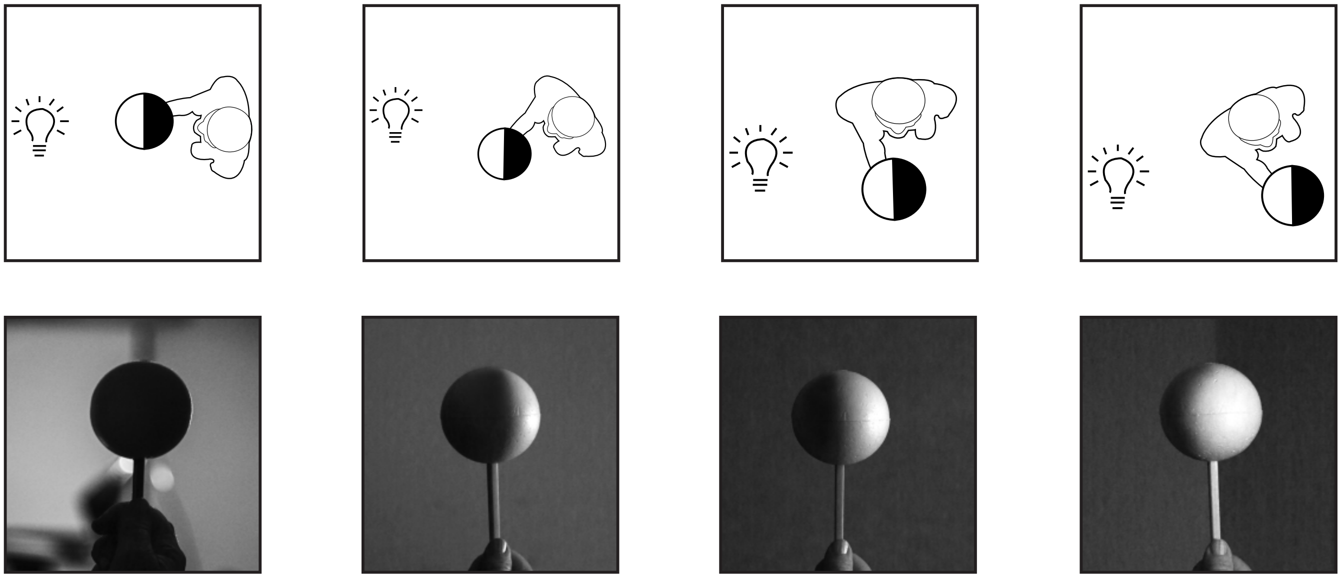
Word Bank

moon	moon phase	orbit	pattern

Name: ______________________ Date: ______________

Write and Share: Student 3

Evidence source: Moon Sphere Model



Prompt: How can we predict how the Moon will change appearance from day to day?

Word Bank

moon	moon phase	orbit	pattern

Name: ____________________ Date: ____________

Modeling the Order of Moon Phases

Launch the *Earth, Moon, and Sun* Modeling Tool activity: Order and Match Views.

Goal: Show which pair of Top View and View from Earth panels would come first, second, and third in time.

Do:

- Tap and drag the Top View panels to put them in the correct order.
- Tap and drag the View from Earth panels to match them to the Top View panels.

Tips:

- In all of the panels, the position of the Moon and light shapes cannot be edited.
- Need help? Turn on the Guide.
- The Top View and View from Earth panels do not start out matched.

When your model is complete, press HAND IN. Write your partner's name here if you had one:

____

Then, answer the questions below.

How can we predict how the Moon will change appearance from day to day?

____

____

____

____

How long does it take for the entire pattern of moon phases to be completed? (check one)

- ☐ It takes about a week.
- ☐ It takes about a month.
- ☐ It takes about a year.
- ☐ It takes a different amount of time each time the pattern repeats.

Name: ____________________ Date: ____________________

Homework: Reading "Gravity in the Solar System"

You've been learning about how the Moon moves around Earth. To widen your view and think about our solar system as a whole, and why planets move around the sun, read and annotate the "Gravity in the Solar System" article. Then, answer the questions below.

What is gravity?

____

____

How does gravity cause the planets to move in a circle around the sun?

____

____

____

____

____

How does gravity cause the solar system to move within the galaxy?

____

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ____________________

Lesson 2.5: Orbit and the Pattern of Moon Phases

Eric Wu's deadline for *About Space* magazine is almost here! He needs to take the pictures of Rupes Cauchy, the Plato crater, and the Copernicus crater soon or he'll be out of a job. Lucky for Eric, you and your fellow student astronomers are nearly ready to make your final recommendations. Today, you'll prepare by completing a paper model that will show Eric why the border between light and dark on the Moon changes location. Then, you'll advise Eric by making a digital model of where the Moon will need to be in its orbit for him to take the photos for *About Space.*

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 2 Question

- Why does the border between light and dark on the Moon change location?

Key Concepts

- From Earth we can only see the half of the Moon that is facing us.
- Because the Moon moves to different positions around Earth, we see different amounts of the illuminated half of the Moon. This is why we see different phases of the Moon.
- There is a pattern to the position of the Moon because the Moon orbits around Earth.
- It takes about one month for the Moon to orbit Earth, so it takes about one month to see the full pattern of moon phases. This pattern repeats with every orbit of the Moon.

Vocabulary

- illuminate
- model
- moon
- moon phase
- orbit
- pattern
- sun

Digital Tools

- *Earth, Moon, and Sun* Modeling Tool activity: Photographing Moon Features

Name: ______________________________ Date: ____________________

Warm-Up

Moon Phases

Think about the experiences you have had during this chapter as you answer the Chapter 2 Question below. You will get a chance to revise your answer later in this lesson.

Why does the border between light and dark on the Moon change location?

____

____

____

____

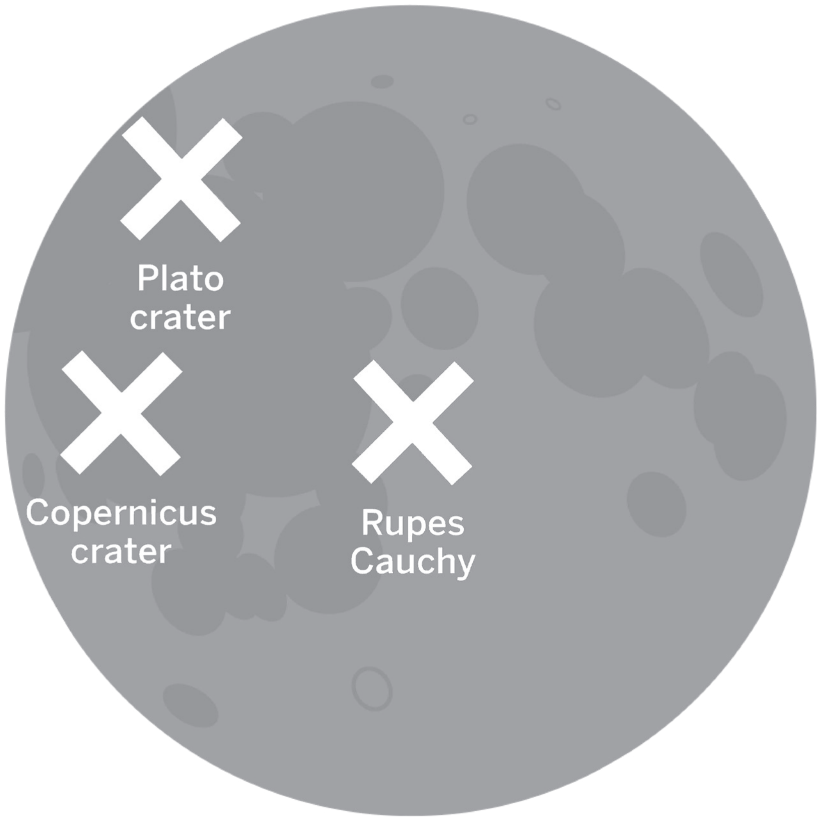
____

____

Name: ______________________________ Date: ____________________

Taking Pictures of the Moon

Before you make your recommendation to Eric Wu, take a few minutes to discuss this question and these claims with your partner. Be sure to discuss which claim you think is best as well as the evidence that supports this claim.



Question: When can Eric Wu take pictures of the three Moon features?

Claim 1: Photographs of these features can be taken on any night.

Claim 2: Photographs of these features can only be taken on some nights.

Name: ______________________________ Date: ______________

Homework: Advising the Astrophotographer

Launch the *Earth, Moon, and Sun* Modeling Tool activity: Photographing Moon Features.

Goal: Show light and dark on the Moon when each moon feature will be on the terminator.

Do:

- In each View from Earth:
  - add and rotate a light shape so the terminator is on the moon feature.
- In each Top View:
  - add a Moon.
  - add and rotate a light shape over it.
  - move the Moon to the position that results in the moon phase shown in View from Earth.

Tips:

- Moon features are indicated by a red X.
- To add a Moon to Top View, tap the pencil and drag a Moon from the toolbar.
- Need help? Turn on the Guide.

When your model is complete, press HAND IN. Write your partner's name here if you had one:

____

When can Eric Wu take pictures of the three Moon features? (check one)

☐ **Claim 1:** Photographs of these features can be taken on any night.

☐ **Claim 2:** Photographs of these features can only be taken on some nights.

Explain how your model supports your claim.

____

____

____

____

Name: ______________________ Date: ______________

Lesson 2.7: Taking on New Challenges

Student astronomers, now that you've made your recommendations to Eric Wu, it's time to put your knowledge of the Earth, Moon, and sun system toward other uses. Today, you'll work with a partner to take on a variety of new challenges, using the Sim and the key concepts from this unit to complete these tasks.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 2 Question

- Why does the border between light and dark on the Moon change location?

Key Concepts

- The Moon does not make its own light; the sun illuminates the Moon.
- When a model is "to scale," object sizes and distances are larger or smaller than in the real world but the same relative to one another. Some models need to be "not to scale" to be useful.
- The sun illuminates the half of the Moon that is facing it, and the other half is dark.
- Light from the sun travels in straight lines.
- From Earth we can only see the half of the Moon that is facing us.
- Because the Moon moves to different positions around Earth, we see different amounts of the illuminated half of the Moon. This is why we see different phases of the Moon.
- There is a pattern to the position of the Moon because the Moon orbits around Earth.
- It takes about one month for the Moon to orbit Earth, so it takes about one month to see the full pattern of moon phases. This pattern repeats with every orbit of the Moon.

Vocabulary

- illuminate
- model
- moon
- moon phase
- orbit
- pattern
- sun

Digital Tools

- *Earth, Moon, and Sun* Simulation

Name: ____________________ Date: ____________

Warm-Up

Reviewing the Key Concepts

Look back at the key concepts that you have learned about during this unit. Then, answer the questions below.

Key Concepts

1. The Moon does not make its own light; the sun illuminates the Moon.
2. When a model is "to scale," object sizes and distances are larger or smaller than in the real world but the same relative to one another. Some models need to be "not to scale" to be useful.
3. The sun illuminates the half of the Moon that is facing it, and the other half is dark.
4. Light from the sun travels in straight lines.
5. From Earth we can only see the half of the Moon that is facing us.
6. Because the Moon moves to different positions around Earth, we see different amounts of the illuminated half of the Moon. This is why we see different phases of the Moon.
7. There is a pattern to the position of the Moon because the Moon orbits around Earth.
8. It takes about one month for the Moon to orbit Earth, so it takes about one month to see the full pattern of moon phases. This pattern repeats with every orbit of the Moon.

Pick a key concept that you understand well and explain it in a way that an elementary school student could understand.

____

____

____

____

Pick a key concept that is confusing to you and record a question below that you would need answered in order to understand it better.

____

____

____

____

Name: ____________________ Date: ____________

Blue Group: Sim Activity

Part 1: Getting Ready for the Science Fair

Your old elementary school is having a science fair. One of your former teachers had an idea when she heard that you were learning about Earth, the Moon, and the sun. She has asked you to help one of her fourth-grade students make a physical model of the Earth, Moon, and sun system for the science fair. The student's name is Marquis, and he has a lot of questions for you about how to build a model.

Goal: Work with your partner to help Marquis, by using Top View in the Sim to answer his questions.

Do:

- Have one partner use the Sim while the other partner records the answer to one of Marquis's questions. Be sure to talk about what you see in the Sim before you record your answers. Switch roles each time you answer a question.

Tip:

- Remember to refer to the key concepts on the classroom wall. These can also help you answer Marquis's questions.

1. Marquis says, "I got some lightbulbs to use in my model. Which parts of my model should I use a lightbulb for?" (check one)

   ☐ Earth

   ☐ Moon

   ☐ sun

   ☐ none of the above

2. Use the Sim or the key concepts to explain your answer to Marquis.

____

____

____

Name: ______________________ Date: ______________

Blue Group: Sim Activity (continued)

3. Marquis says, "What should the Moon look like in my model?" (check one)

   - ☐ light on both sides
   - ☐ light on the side facing the sun and dark on the other side
   - ☐ dark on the side facing the sun and light on the other side
   - ☐ dark on both sides

4. Use the Sim or the key concepts to explain your answer to Marquis.

____

____

____

5. Marquis says, "I want to include a drawing that shows how light moves in my model. How should I draw the light?" (check one)

   - ☐ straight arrows coming from the sun
   - ☐ curved arrows coming from the sun
   - ☐ straight arrows coming from the Moon
   - ☐ curved arrows coming from the Moon

6. Use the Sim or the key concepts to explain your answer to Marquis.

____

____

____

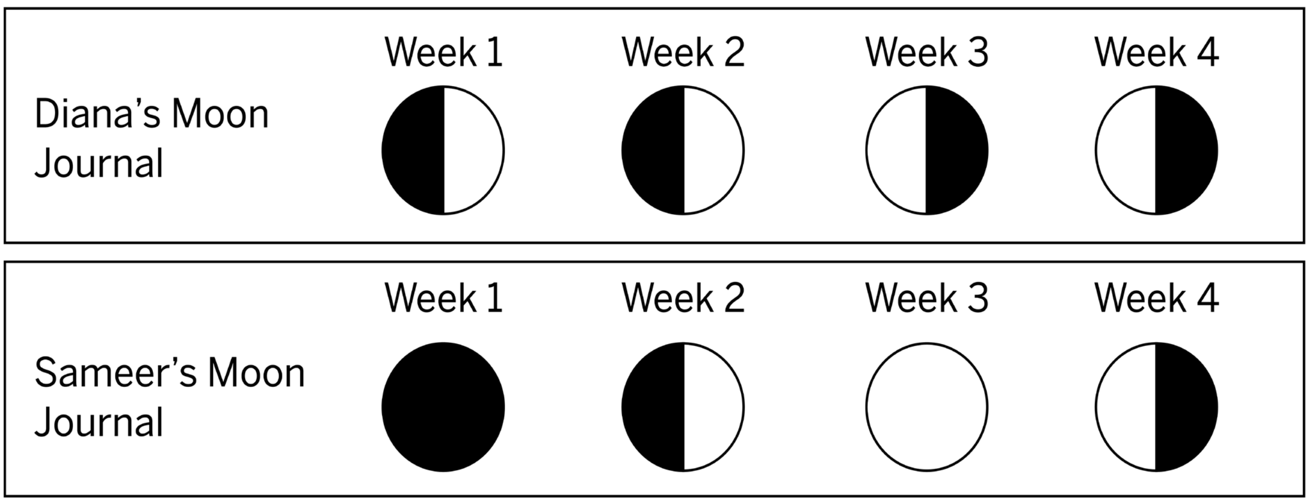
Name: ______________________ Date: ______________

Blue Group: Sim Activity (continued)

Part 2: Who did their Moon Journal homework?

Now that you've helped Marquis, your former teacher needs your help on something else. Last month, two of her students, Diana and Sameer, each had to make a Moon Journal for homework. Both students were supposed to go outside at night once each week, observe the Moon, and draw a picture to show what it looked like on that night.

When Diana and Sameer turned in their Moon Journals this morning, the teacher noticed that the drawings in each Moon Journal looked different. She thinks that one of her students did not go outside to observe the Moon at night and instead tried to draw in their Moon Journal that morning before class. The teacher would like you to identify which student recorded a series of moon phases that could not have been observed in a single month.



Goal: With a partner, use the Sim to gather evidence about the appearance of the Moon to help you respond to the teacher.

Do:

- Use both Top View and View from Earth to answer the questions on the next page.
- Have one partner use the Sim while the other partner records the answer to each question. Be sure to talk about what you see in the Sim before you record your answers. Switch roles each time you answer a question.

Tips:

- Choose a single month to observe. Remember that the students only had four weeks to make their Moon Journals.
- Remember to refer to the key concepts on the classroom wall. These can also help you answer the questions.

Name: ______________________ Date: ______________

Blue Group: Sim Activity (continued)

1. How is the appearance of the Moon different in View from Earth than it is in Top View? (choose all answers that apply)
   - ☐ The appearance of the Moon changes a lot **more** in View from Earth than it does in Top View.
   - ☐ The appearance of the Moon changes a lot **less** in View from Earth than it does in Top View.
   - ☐ The Moon sometimes appears to be fully illuminated in View from Earth but **never** appears to be fully illuminated in Top View.
   - ☐ The Moon never appears to be fully illuminated in View from Earth but it **sometimes** appears to be fully illuminated in Top View.

2. What determines the appearance of the Moon in View from Earth? (check one)
   - ☐ the position of the Moon around Earth
   - ☐ the position of Earth's shadow on the Moon
   - ☐ the amount of light coming from the sun
   - ☐ the direction that the light side of the Moon is facing

3. How long does it take for the Moon to go around Earth? (check one)
   - ☐ about one day
   - ☐ about one week
   - ☐ about one month
   - ☐ about one year

4. How often are we able to observe each moon phase? (check one)
   - ☐ about 1 or 2 times a day
   - ☐ about 1 or 2 times a week
   - ☐ about 1 or 2 times a month
   - ☐ about 1 or 2 times a year

5. How long does it take for us to observe the same moon phase twice? (check one)
   - ☐ about 1 week
   - ☐ about 2 weeks
   - ☐ about 1 month
   - ☐ about 2 months

Name: ______________________________ Date: ________________

Blue Group: Sim Activity (continued)

Now that you've gathered evidence in the Sim, look back at Diana's and Sameer's Moon Journals (on page 52). Then, identify the student who needs to repeat the Moon Journal assignment next month and explain why.

Which student recorded a series of moon phases that could not have been observed in a single month? (check one)

☐ Diana

☐ Sameer

Explain why the series of moon phases that the student recorded could not have been observed in a single month. Use the evidence you gathered from the Sim or the key concepts on the classroom wall to help you explain.

____

____

____

____

____

____

____

____

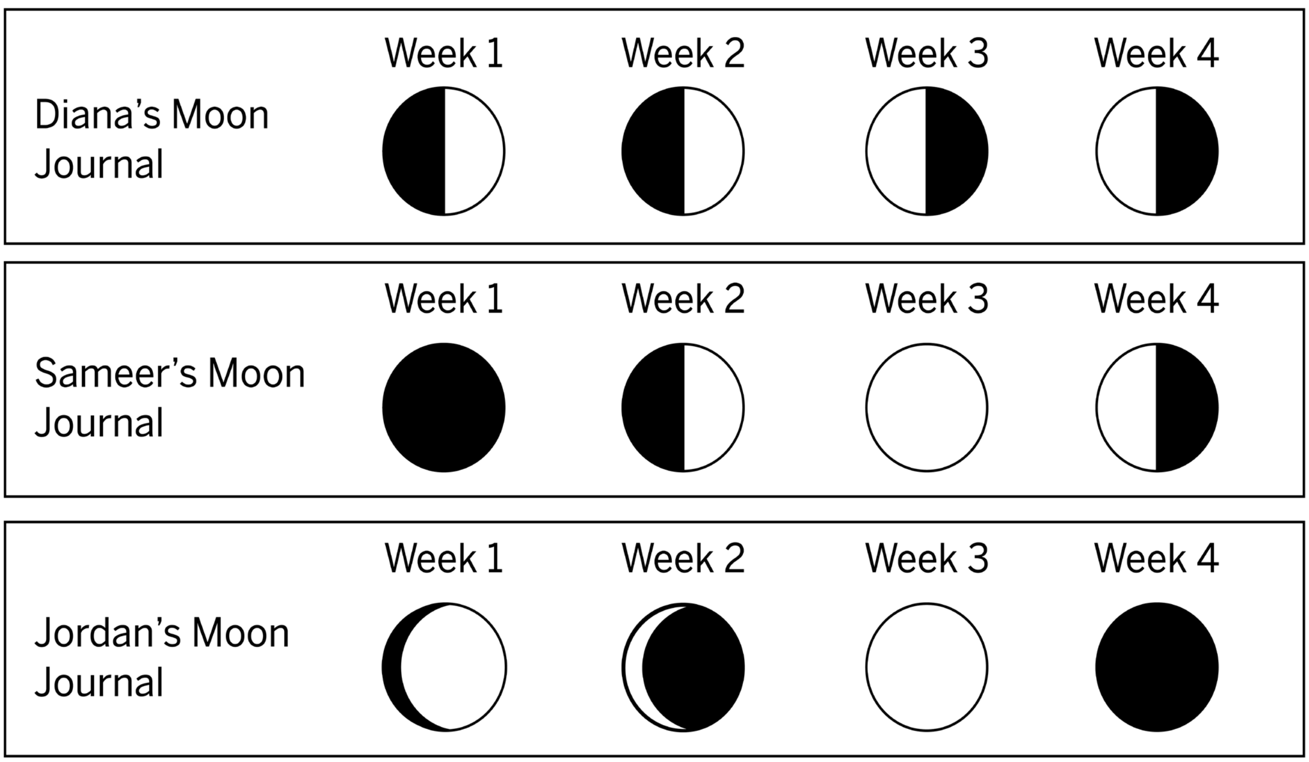
Name: ____________________ Date: ____________

Purple Group: Sim Activity

Who did their Moon Journal homework?

One of the teachers at your old elementary school heard that you were learning about the Earth, the Moon, and sun and asked you to help her with something. Last month, three of her students, Diana, Sameer, and Jordan, each had to make a Moon Journal for homework. Each student was supposed to go outside at night once each week, observe the Moon, and draw a picture to show what it looked like on that night.

When Diana, Sameer, and Jordan turned in their Moon Journals this morning, the teacher noticed that the drawings in each Moon Journal looked different. She thinks that one of her students did not go outside to observe the Moon at night and instead tried to draw in their Moon Journal that morning before class. The teacher would like you to identify which student or students recorded a series of moon phases that could not have been observed in a single month.



Name: ______________________________ Date: ________________

Purple Group: Sim Activity (continued)

Goal: With a partner, use the Sim to gather evidence about the appearance of the Moon to help you respond to the teacher.

Do:

- Use both Top View and View from Earth to answer the questions below.
- Have one partner use the Sim while the other partner records the answer to each question. Be sure to talk about what you see in the Sim before you record your answers. Switch roles each time you answer a question.

Tips:

- Choose a single month to observe. Remember that the students only had four weeks to make their Moon Journals.
- Remember to refer to the key concepts on the classroom wall. These can also help you answer the questions.

1. How is the appearance of the Moon different in View from Earth than it is in Top View? (choose all answers that apply)
   - ☐ The appearance of the Moon changes a lot **more** in View from Earth than it does in Top View.
   - ☐ The appearance of the Moon changes a lot **less** in View from Earth than it does in Top View.
   - ☐ The Moon sometimes appears to be fully illuminated in View from Earth but **never** appears to be fully illuminated in Top View.
   - ☐ The Moon never appears to be fully illuminated in View from Earth but it **sometimes** appears to be fully illuminated in Top View.

2. What determines the appearance of the Moon in View from Earth? (check one)
   - ☐ the position of the Moon around Earth
   - ☐ the position of Earth's shadow on the Moon
   - ☐ the amount of light coming from the sun
   - ☐ the direction that the light side of the Moon is facing

3. How long does it take for the Moon to go around Earth? (check one)
   - ☐ about one day
   - ☐ about one week
   - ☐ about one month
   - ☐ about one year

Name: ______________________________ Date: ________________

Purple Group: Sim Activity (continued)

4. How often are we able to observe each moon phase? (check one)
   - ☐ about 1 or 2 times a day
   - ☐ about 1 or 2 times a week
   - ☐ about 1 or 2 times a month
   - ☐ about 1 or 2 times a year

5. How long does it take for us to observe the same moon phase twice? (check one)
   - ☐ about 1 week
   - ☐ about 2 weeks
   - ☐ about 1 month
   - ☐ about 2 months

Now that you've gathered evidence in the Sim, look back at Diana's, Sameer's, and Jordan's Moon Journals (on page 55). Then, identify the student or students who need to repeat the Moon Journal assignment next month and explain why.

Which student or students recorded a series of moon phases that could not have been observed in a single month? (choose all that apply)

- ☐ Diana
- ☐ Sameer
- ☐ Jordan

Explain why each of the series of moon phases that the student(s) recorded could not have been observed in a single month. Use the evidence you gathered from the Sim or the key concepts on the classroom wall to help you explain.

____

____

____

____

____

____

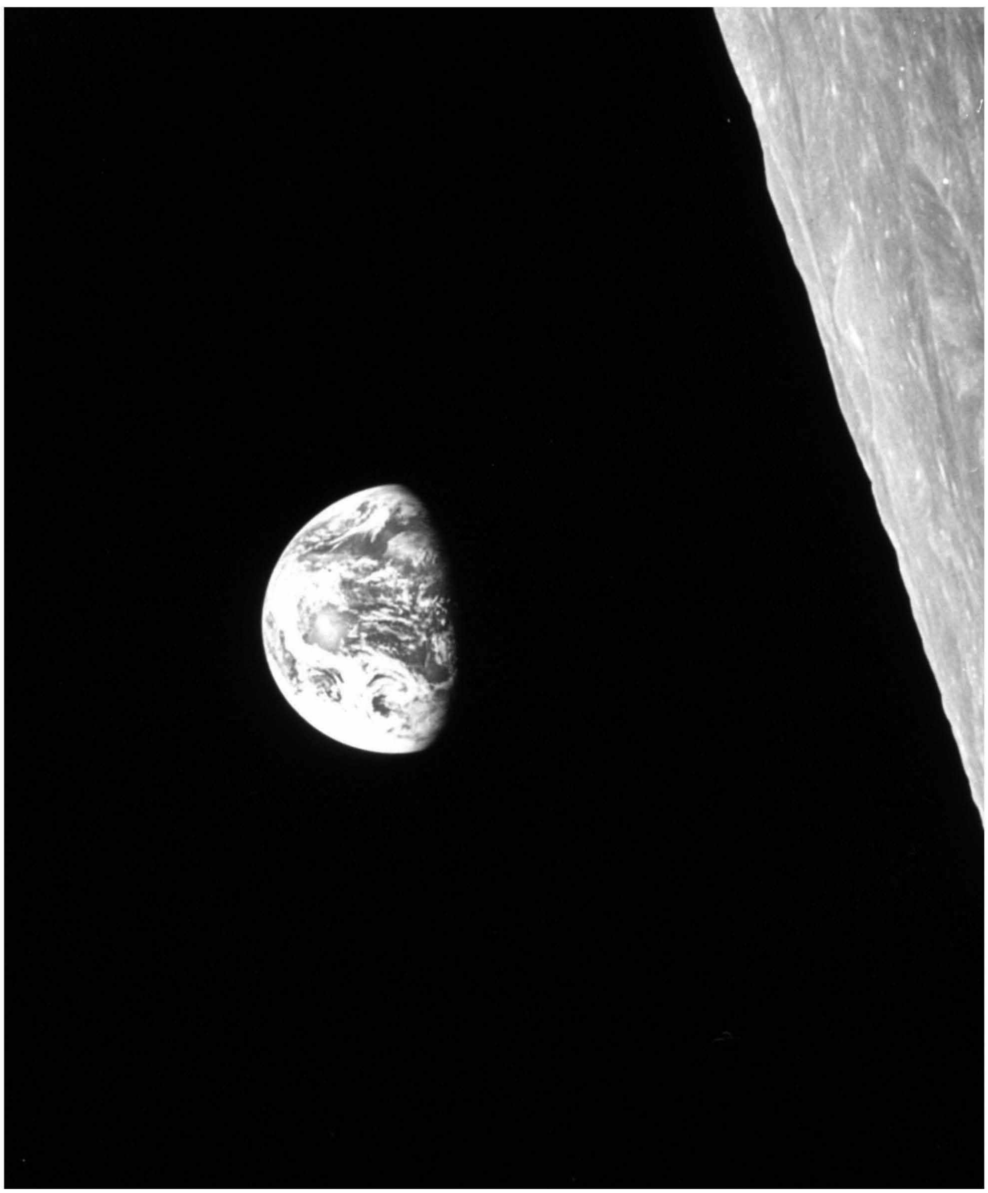
Name: ______________________________ Date: ____________________

Green Group: Sim Activity

Part 1: Seeing Phases of Earth from the Moon

The last chapter focused on the different phases of the Moon that we observe from Earth. However, the Moon is not the only object in the solar system that has phases. When astronauts visit the Moon and look back at Earth, they see phases, too! Like the phases of the Moon that we see from Earth, the phases of Earth that astronauts see from the Moon are determined by the position of the Moon in its orbit around Earth. Today, you're going to investigate the phases of Earth.

This photograph of Earth was taken by NASA astronauts from the Moon during the Apollo 8 mission in 1968. Which phase does Earth appear to be in?



Name: ______________________________ Date: ______________

Green Group: Sim Activity (continued)

Goal: With a partner, use the Sim to investigate the phases of Earth that astronauts see from the Moon.

Do:

- Use both Top View and View from Earth to answer the questions below.
- Have one partner use the Sim while the other partner records the answer to each question. Be sure to talk about what you see in the Sim before you record your answers. Switch roles each time you answer a question.

Tips:

- Move the Moon to create the phase described in each question below.
- Investigate Top View and imagine that you are an astronaut standing on the Moon and looking back at Earth.
- Remember to refer to the key concepts on the classroom wall. These can also help you answer the questions.

Complete the statements below using the word bank below.

Word Bank

new Earth phase	crescent Earth phase	quarter Earth phase
gibbous Earth phase	full Earth phase	

1. When the View from Earth is a **new moon phase,** the View from the Moon

   would be a ______________________.

2. When the View from Earth is a **full moon phase,** the View from the Moon

   would be a ______________________.

3. When the View from Earth is a **crescent moon phase,** the View from the Moon

   would be a ______________________.

4. When the View from Earth is a **quarter moon phase,** the View from the Moon

   would be a ______________________.

5. When the View from Earth is a **gibbous moon phase,** the View from the Moon

   would be a ______________________.

Name: ____________________ Date: ____________

Green Group: Sim Activity (continued)

Part 2: Seeing Phases of Earth from the Moon

Turn back to page 58 and look at the image. Then, use what you have learned from the Sim to answer the questions.

When the astronaut took this photo of Earth, what moon phase would have been visible in View from Earth? (check one)

- ☐ new moon
- ☐ crescent moon
- ☐ quarter moon
- ☐ gibbous moon
- ☐ full moon

Explain your answer.

____

____

____

____

Where was the sun in relation to Earth when the astronaut took this photo? (check one)

- ☐ the sun was above Earth
- ☐ the sun was below Earth
- ☐ the sun was to the left of Earth
- ☐ the sun was to the right of Earth

Explain your answer.

____

____

____

____

Name: ______________________ Date: ______________

Green Group: Sim Activity (continued)

Part 3: Seeing Phases from the Sun

So far, we've thought about seeing phases from Earth and from the Moon. But imagine for a moment that you could safely stand on the sun. What would Earth and the Moon look like to an observer on the sun?

Goal: With a partner, use the Sim to think about how Earth and the Moon would appear to an observer on the sun on May 22, 2025.

Do:

- Use both Top View and View from Earth to answer the questions below.
- Have one partner use the Sim while the other partner records the answer to each question. Be sure to talk about what you see in the Sim before you record your answers. Switch roles each time you answer a question.

Tips:

- Think about your experiences with the Moon Sphere Model. Try to imagine yourself standing just below the light at the center of the classroom and looking out at your classmates holding their Moon spheres.
- Remember to refer to the key concepts on the classroom wall. These can also help you answer the questions.

1. What moon phase would an observer on the sun see on May 22, 2025? (check one)

   ☐ new moon

   ☐ crescent moon

   ☐ quarter moon

   ☐ gibbous moon

   ☐ full moon

2. What Earth phase would an observer on the sun see on May 22, 2025? (check one)

   ☐ new Earth

   ☐ crescent Earth

   ☐ quarter Earth

   ☐ gibbous Earth

   ☐ full Earth

Name: ________________________________ Date: ____________________

Green Group: Sim Activity (continued)

3. Would Earth and the Moon look different to an observer on the sun on another date in 2025? (check one)

   ☐ yes

   ☐ no

Explain your answer.

____

____

____

____

Name: ______________________ Date: ______________

Sharing Results

Reflecting on the Sim

Take a minute to think about what you learned today. As you think, ask yourself these questions:

- Did the Sim activities help you better understand any of the key concepts?
- Did the Sim activities help you learn something new?

Name: ______________________ Date: ______________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. You have been investigating what determines the appearance of the Moon from Earth, in order to tell astrophotographer Eric Wu when he can take photographs. Are you getting closer to understanding what determines the Moon's appearance?

1. I understand where the Moon gets its light. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

2. I understand why we see different phases of the Moon. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

3. I understand what causes the pattern of the Moon's phases. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

Name: ______________________________ Date: ________________

Homework: Check Your Understanding (continued)

4. I understand what happens during a lunar eclipse. (check one)

- ☐ yes
- ☐ not yet

Explain your answer choice.

____

____

5. I understand why lunar eclipses happen. (check one)

- ☐ yes
- ☐ not yet

____

____

6. What do you still wonder about what determines the Moon's appearance from Earth?

____

____

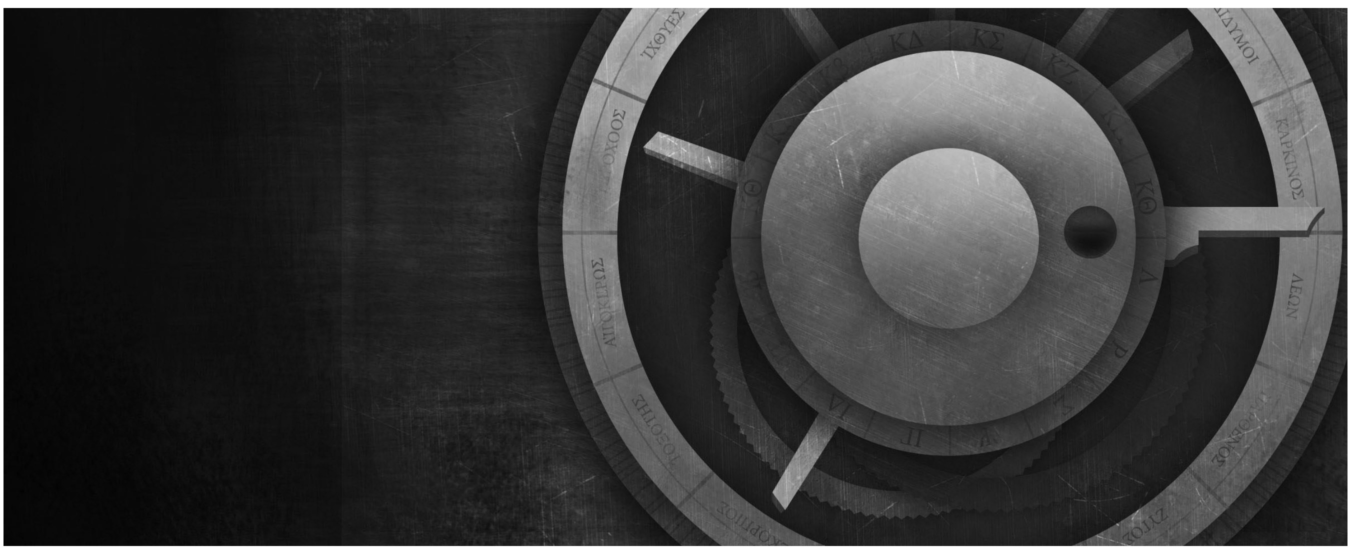
____

____

Name: ______________________ Date: ______________

Chapter 3: Lunar Eclipses
Chapter Overview

By now you know that the sun illuminates half of the Moon, whether we can see it or not. However, a lunar eclipse is a special exception to this rule. During this chapter, you'll learn why lunar eclipses happen so that you can advise Eric Wu on when to photograph one for *About Space* magazine.



Name: ______________________ Date: ______________

Lesson 3.1: Introduction to Lunar Eclipses

Congratulations, you did a great job advising Eric Wu about moon phases! Now, he wants your help with his next assignment: photographing a lunar eclipse. Have you seen a lunar eclipse? Why would the Moon occasionally go completely dark, right in the middle of its normal path through the night sky? In today's lesson, you will be learning about lunar eclipses using the Moon Sphere Model and the *Earth, Moon, and Sun* Simulation.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 3 Question

- What are the conditions that cause a lunar eclipse?

Vocabulary

- illuminate
- lunar eclipse
- model
- moon
- moon phase
- orbit
- scale
- sun

Digital Tools

- *Earth, Moon, and Sun* Simulation
- *Earth, Moon, and Sun* Modeling Tool activity: Modeling a Lunar Eclipse

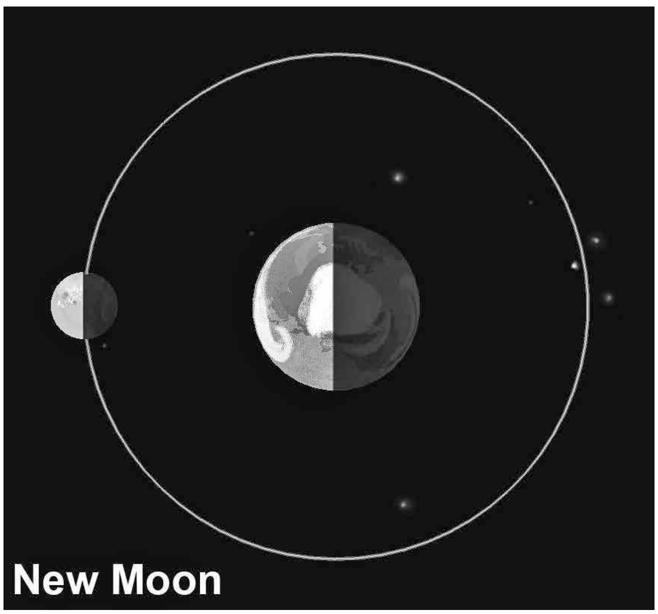
Name: ______________________ Date: ______________

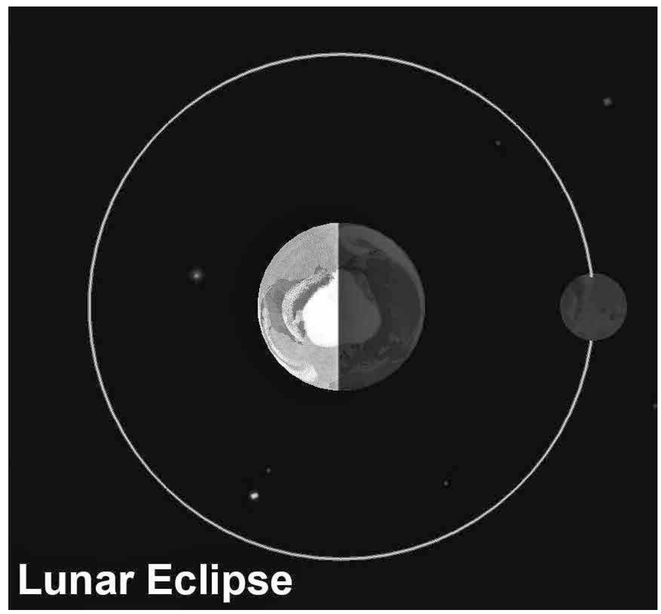
Warm-Up

Thinking About Lunar Eclipses

Look at the images below and then answer the question. Be sure to share your ideas with your partner.

The images below show the Moon during new moon phase and the Moon during a lunar eclipse. The images are from Top View.





How are the Moon during new moon phase and the Moon during a lunar eclipse different?

____

____

____

____

____

____

Name: ______________________ Date: ______________

The Moon Sphere Model: Lunar Eclipses

Part 1: Corresponding with the Astrophotographer

To: Student Astronomers
From: Eric Wu, Astrophotographer
Subject: Lunar Eclipses

Thank you so much for your assistance in determining when I could photograph Rupes Cauchy and the Copernicus and Plato craters. The editors were really happy with the photographs!

Now, they have asked me to photograph a lunar eclipse for a story in the next issue. I do not know that much about lunar eclipses, so I need your assistance to help me determine when I can photograph one. I will also have to write some captions for my photos, so I will need to know some background information about what causes lunar eclipses, as well.

Part 2: Modeling an Eclipse

Work with your partner to try to model a lunar eclipse. Then, answer the questions below.

How were you able to make your Moon sphere completely dark?

____

____

____

____

Use your Moon sphere to help you complete the following statement using one of the words below:

A lunar eclipse can occur when the Moon is in ______________ in its orbit.

any position **a few different positions** **one position**

Name: ______________________ Date: ______________

Exploring Lunar Eclipses

Part 1: Three View Mode in the Simulation

Goal: With your partner, explore Three View Mode of the Sim and discuss what you learn about System View.

Tips:

- Use the cameras (pink camera toggle) to see how Top View and View from Earth are generated.
- Change the perspective in System View, using the slider on the left.

Part 2: Investigating Lunar Eclipses

Goal: Find a lunar eclipse in the *Earth, Moon, and Sun* Simulation and explore the different views to answer the question: *What makes the Moon completely dark during a lunar eclipse?*

Tips:

- There will be a lunar eclipse in July, August, or September in 2025.
- You may find it helpful to move time slowly, using the day and hour timeline sliders.

In the box below, draw what the System View and Top View look like in the Sim during a lunar eclipse.

Consider the positions of Earth, the Moon, and the sun as you answer the question: *What makes the Moon completely dark during a lunar eclipse?*

____

____

____

____

Name: ______________________ Date: ______________

Homework: Modeling a Lunar Eclipse

Launch the *Earth, Moon, and Sun* Modeling Tool activity: Modeling a Lunar Eclipse.

Goal: Model a lunar eclipse by showing the positions of Earth and the Moon as well as how the Moon is illuminated.

Do:

- In the View from Earth panel:
  - add and rotate a light shape on the Moon.
- In the Top View panel:
  - place a moon in a position around Earth.
  - add and rotate a light shape on the Moon.
- In the System View panel:
  - select one of the two options to show the positions of Earth, the Moon, and the sun.

Tips:

- To edit a panel, press the pencil.
- You can add a light shape to Earth, but you do not need to.
- You'll be revising this model in Lesson 3.3.

If you have any new ideas after completing your model, take time to revise your earlier answer to the question: *What makes the Moon completely dark during a lunar eclipse?*

____

____

____

____

Name: ______________________________ Date: ______________

Homework: Reading "The Endless Summer of the Arctic Tern"

You have been focused on the Moon and how it appears at different times according to the positions of the Earth, Moon, and sun. To learn about another important phenomenon that results from the changing position of the Earth relative to the sun, read and annotate the "The Endless Summer of the Arctic Tern" article. Then, answer the questions below.

Why are there seasons on Earth?

____

____

____

____

Why is there one winter and one summer each year?

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________________ Date: ________________

Lesson 3.2: Reading About Predicting Eclipses

Today, you will read an article about an ancient mechanism used to predict many things about the movement of the planets. You will be using Active Reading strategies to read and annotate the article and then share your thinking with your classmates. Information from this article will help you understand why lunar eclipses happen when they do, which you'll need to know if you want to advise Eric Wu about when eclipses can be photographed.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 3 Question

- What are the conditions that cause a lunar eclipse?

Key Concepts

- During a lunar eclipse, the Moon is completely dark because Earth blocks sunlight from hitting the Moon.
- Lunar eclipses can only happen when Earth is in between the sun and the Moon.

Vocabulary

- illuminate
- lunar eclipse
- moon
- moon phase
- orbit
- pattern
- sun

Name: ____________________ Date: ____________

Warm-Up

Thinking About Eclipses

Think about what you have learned from the Moon Sphere Model and the Simulation activities as you answer the questions below.

Image 1

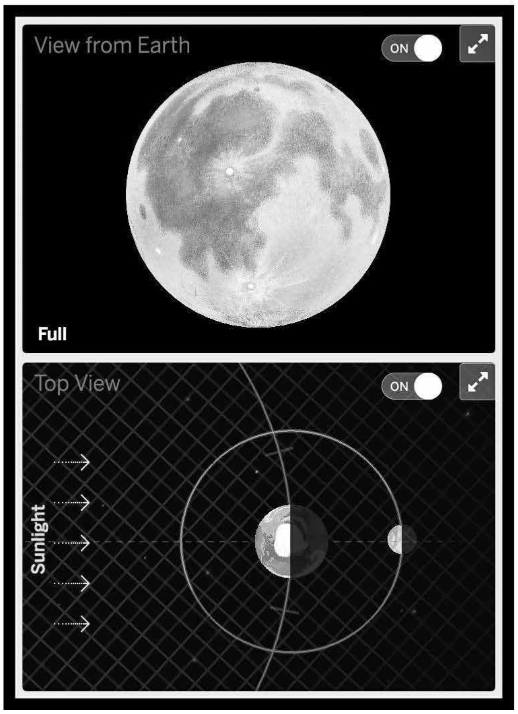
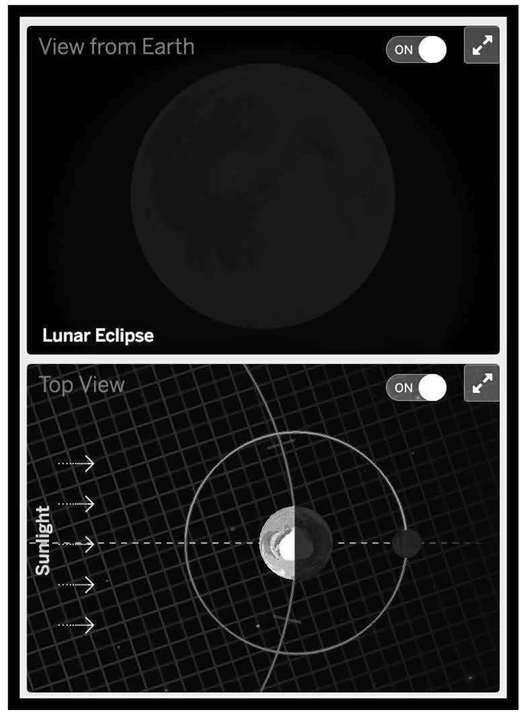


Image 2



Why is a lunar eclipse happening in Image 2? (check one)

- ☐ The Moon is directly in between Earth and the sun, in a straight line.
- ☐ The illuminated half of the Moon is facing away from Earth.
- ☐ The Moon is far away from the sun, so the sun's light is weaker.
- ☐ Earth is blocking the sun's light from hitting the Moon.

If Earth is in between the sun and the Moon in both Image 1 and Image 2, why do you think a lunar eclipse is only happening in Image 2?

____

____

____

____

Name: ______________________________ Date: ______________

Reading “An Ancient Machine for Predicting Eclipses”

1. Read and annotate the article “An Ancient Machine for Predicting Eclipses.”
2. Choose and mark annotations to discuss with your partner. Once you have discussed these annotations, mark them as discussed.
3. Now, choose and mark a question or connection, either one you already discussed or a different one you still want to discuss with the class.
4. Answer the reflection question below.

What is something about the text that you discussed with your partner?

____

____

____

____

Active Reading Guidelines

1. Think carefully about what you read. Pay attention to your own understanding.
2. As you read, annotate the text to make a record of your thinking. Highlight challenging words and add notes to record questions and make connections to your own experience.
3. Examine all visual representations carefully. Consider how they go together with the text.
4. After you read, discuss what you have read with others to help you better understand the text.

Name: ______________________ Date: ______________

Homework: Making Connections

Think of another science topic you studied earlier. How might considering scale be useful when investigating that topic? How is that similar to and different from how the crosscutting concept of Scale is useful in this unit?

Name: ______________________________ Date: ____________________

Lesson 3.3: Gathering Evidence About Lunar Eclipses

Student astronomers, in the last lesson you read about the Antikythera mechanism, an ancient set of metal gears used more than 2,000 years ago to predict lunar eclipses. But why are lunar eclipses so hard to predict in the first place? Why don't lunar eclipses happen every month, like the phases of the Moon that you learned about in Chapter 2? Today, you'll use the Sim and revisit "An Ancient Machine for Predicting Eclipses" to gather evidence about these questions.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 3 Question

- What are the conditions that cause a lunar eclipse?

Key Concepts

- During a lunar eclipse, the Moon is completely dark because Earth blocks sunlight from hitting the Moon.
- Lunar eclipses can only happen when Earth is in between the sun and the Moon.

Vocabulary

- illuminate
- lunar eclipse
- model
- moon
- moon phase
- orbit
- sun

Digital Tools

- *Earth, Moon, and Sun* Simulation
- *Earth, Moon, and Sun* Modeling Tool activity: Modeling a Lunar Eclipse
- *Earth, Moon, and Sun* Modeling Tool activity: Modeling a Full Moon

Name: ______________________________ Date: ________________

Warm-Up

During this lesson, you will have a chance to gather evidence that will help you answer the Investigation Question. However, scientists often start an investigation by making a claim based on their initial ideas about a question.

Think about the Investigation Question and write your initial claim about it below. You will get a chance to revise your claim at the end of this lesson.

Why isn't there a lunar eclipse every time Earth is in between the sun and the Moon?

____

____

____

____

____

____

Name: ______________________________ Date: ________________

Gathering Evidence from the Sim

Goal: With a partner, use the *Earth, Moon, and Sun* Simulation to gather evidence that will help you answer the Investigation Question.

Do:

- One partner will find a lunar eclipse in July, August, or September and display it on his device.
- One partner will find a full moon in July, August, or September and display it on her device.
- Partners will use both devices to compare the positions of Earth, the Moon, and the sun during a lunar eclipse and during a full moon.
- Partners discuss any similarities or differences that might help answer the Investigation Question.

Tips:

- Be sure to use both System View and Top View when comparing the lunar eclipse and the full moon.
- Use the slider on the left-hand side of the screen in System View to change the perspective.
- Record your evidence by writing or drawing your observations in the space below.

Investigation Question: *Why isn't there a lunar eclipse every time Earth is in between the sun and the Moon?*

Name: ________________________________ Date: ____________________

Gathering Evidence from a Text

Reread the last paragraph of "An Ancient Machine for Predicting Eclipses." As you read, highlight or make annotations about any evidence that might help you explain why there isn't a lunar eclipse every time Earth is in between the sun and the Moon. Then, discuss this evidence with your partner and share your current ideas about the Investigation Question.

Investigation Question: *Why isn't there a lunar eclipse every time Earth is in between the sun and the Moon?*

Name: ______________________________ Date: ______________

Modeling a Lunar Eclipse and a Full Moon

Part 1: Modeling a Lunar Eclipse

Goal: Review your model in the *Earth, Moon, and Sun* Modeling Tool activity: Modeling a Lunar Eclipse. If necessary, revise this model so that it shows your current thinking about lunar eclipses.

When your model is complete, press HAND IN. Write your partner's name here if you had one:

____

Part 2: Modeling a Full Moon

Goal: Complete the *Earth, Moon, and Sun* Modeling Tool activity: Modeling a Full Moon. Model a full moon by showing the positions of Earth and the Moon and how the Moon is illuminated.

Do:

- In the View from Earth panel:
  - add and rotate a light shape on the Moon.
- In the Top View panel:
  - place a moon in a position around Earth.
  - add and rotate a light shape on the Moon.
- In the System View panel:
  - select one of the two options to show the positions of Earth and the Moon.

Tips:

- To edit a panel, press the pencil.
- You can add a light shape to Earth, but you do not need to.

When your model is complete, press HAND IN. Write your partner's name here if you had one:

______________________________. Then, answer the question below.

Revise your Warm-Up response to the question: *Why isn't there a lunar eclipse every time Earth is in between the sun and the Moon?*

____

____

____

Name: ______________________________ Date: ________________

Homework: Exploring Solar Eclipses

You've learned how to predict and explain lunar eclipses. Can you use what you've learned to try to explain another kind of eclipse, a solar eclipse?

1. Start by writing your initial ideas about solar eclipses. What are they? When do you think they happen?

____

____

____

2. Find and observe a solar eclipse in the *Earth, Moon, and Sun* Simulation. **Hint:** One takes place on September 21. Describe what you observed.

____

____

____

____

____

3. Solar eclipses happen when the Moon is in **full moon phase** / **new moon phase** / **any phase.** (circle one)

4. Why don't solar eclipses happen every time the Moon is in between the sun and Earth?

____

____

____

____

____

Name: ____________________ Date: ____________

Lesson 3.4: When and Why We See Lunar Eclipses

This is it! Eric Wu needs to know when and why lunar eclipses happen and, by the end of this lesson, you'll be ready to tell him. In the meantime, you and your fellow student astronomers will review the evidence you have gathered throughout this chapter and discuss how it can be used to make the most convincing argument for Eric. Will Eric get the photos he needs and make his deadline for *About Space* magazine? It's up to you, student astronomers!

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 3 Question

- What are the conditions that cause a lunar eclipse?

Key Concepts

- During a lunar eclipse, the Moon is completely dark because Earth blocks sunlight from hitting the Moon.
- Lunar eclipses can only happen when Earth is in between the sun and the Moon.
- Lunar eclipses do not happen every time Earth is in between the sun and the Moon.
- The Moon is only completely dark when the sun, Earth, and the Moon are in a straight line, with Earth in the middle.

Vocabulary

- illuminate
- lunar eclipse
- model
- moon
- moon phase
- orbit
- pattern
- sun

Name: ______________________ Date: ______________

Warm-Up

Two Claims About Lunar Eclipses

Read the story below about Chloe and Khalil, two students from another school who are also learning about the Earth, Moon, and sun. Then, answer the question below.

> Chloe is a photographer for the school newspaper. After learning about Eric Wu's assignment for *About Space* magazine, she decided to try to take her own picture of a lunar eclipse for the school newspaper. However, on the night of the lunar eclipse, Chloe wasn't feeling well, so her parents wouldn't let her go outside with her camera.
>
> The next day at school, Chloe was feeling disappointed, so her friend Khalil tried to cheer her up. "Don't worry," he said. "Remember, we learned that the Moon moves in the same circle around Earth each month. That means you can photograph a lunar eclipse when Earth is in between the sun and the Moon again next month."
>
> "Maybe, but maybe not," Chloe said. "A lunar eclipse happens sometimes when Earth is in between the sun and the Moon, but not always. It could be a long time before I have another opportunity to take a picture of a lunar eclipse."

When can a lunar eclipse be photographed? (check one)

- ☐ **Claim 1:** A lunar eclipse can be photographed any time Earth is in between the sun and the Moon.
- ☐ **Claim 2:** A lunar eclipse can be photographed sometimes when Earth is in between the sun and the Moon.

Name: ______________________________ Date: ________________

Write and Share Routine: Discussing Lunar Eclipses

Find the sheet on the next 3 pages that has the number you were assigned (1, 2, or 3). Follow the instructions below to participate in the Write and Share routine.

1. Carefully read and annotate the information you are given.
2. Answer your prompt, using these vocabulary words: *moon, moon phase, orbit, pattern.*
3. After everyone in your group has had a chance to write, take turns introducing your prompts and sharing your responses.
4. While one student is presenting, the other two listen carefully.
5. After each student presents, the other students in the group can ask questions or make comments.

Name: ______________________________ Date: ____________________

Write and Share Routine: Student 1

Evidence source: "An Ancient Machine for Predicting Eclipses" article

> "Today astronomers can explain why lunar eclipses happen when they do. Lunar eclipses are caused by Earth blocking sunlight from reaching the Moon. For Earth to block the sunlight, it has to be between the sun and the Moon. Not only that, but the sun, Earth, and the Moon have to line up exactly, with Earth in the middle. When they line up in this way, Earth blocks the sunlight and the Moon goes dark. Eclipses only happen on the night of a full moon, because the full moon is the phase when the sun, Earth, and the Moon line up with Earth in the middle."

Prompt: What are the conditions that cause a lunar eclipse?

Word Bank

illuminate	lunar eclipse	moon
orbit	sun	

____

____

____

____

____

____

____

____

____

____

____

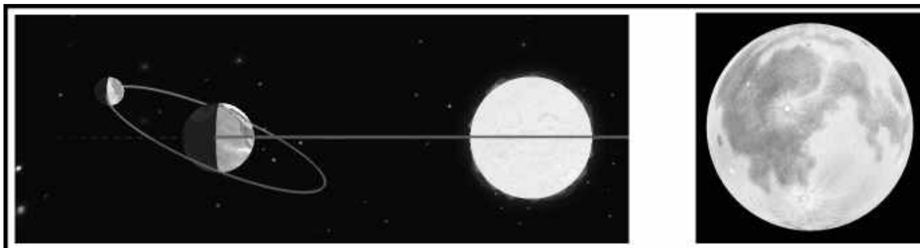
____

____

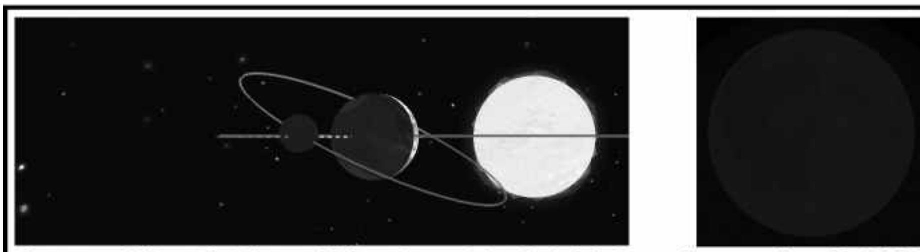
Name: ____________________ Date: ____________________

Write and Share Routine: Student 2

Evidence source: ***Earth, Moon, and Sun*** **Sim**



System View (left) and View from Earth (right) on July 10, 2025



System View (left) and View from Earth (right) on September 7, 2025

Prompt: What are the conditions that cause a lunar eclipse?

Word Bank

illuminate	lunar eclipse	moon
orbit	sun	

____

____

____

____

____

____

____

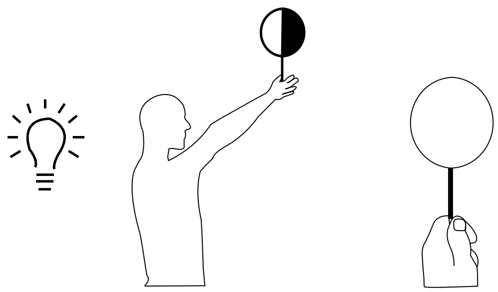
____

____

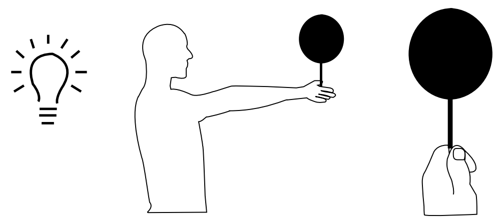
Name: ______________________________ Date: ______________

Write and Share Routine: Student 3

Evidence source: Moon Sphere Model



Moon Sphere Model: Position #1



Moon Sphere Model: Position #2

Prompt: What are the conditions that cause a lunar eclipse?

Word Bank

illuminate	lunar eclipse	moon
orbit	sun	

____

____

____

____

____

____

____

____

____

Name: ______________________ Date: ______________

Reasoning About Photographing an Eclipse

With your group, use the Reasoning Tool to connect each piece of evidence to the claim you think is correct.

Question: When can a lunar eclipse be photographed?

☐ **Claim 1:** A lunar eclipse can be photographed anytime Earth is in between the sun and the Moon.

☐ **Claim 2:** A lunar eclipse can be photographed sometimes when Earth is in between the sun and the Moon.

Evidence	**This matters because . . .**	**Therefore, . . .** (claim)
Example evidence: Two Top View images		
Evidence source: "An Ancient Machine for Predicting Eclipses" article		
Evidence source: *Earth, Moon, and Sun* Sim		
Evidence source: Moon Sphere Model		

Name: ______________________ Date: ______________

Homework: Advising the Astrophotographer

Use the evidence you discussed with your group during the Write and Share routine and recorded in the Reasoning Tool to help you write a message to Eric Wu about photographing a lunar eclipse. You may wish to use some of the vocabulary words listed in the word bank below to help you write.

Question: When can a lunar eclipse be photographed?

☐ **Claim 1:** A lunar eclipse can be photographed anytime Earth is in between the sun and the Moon.

☐ **Claim 2:** A lunar eclipse can be photographed sometimes when Earth is in between the sun and the Moon.

Word Bank

illuminate	lunar eclipse	moon
orbit	sun	model

Write a message to Eric Wu explaining when he can photograph a lunar eclipse and why lunar eclipses happen.

- First, state your claim about when a lunar eclipse can be photographed.
- Then, use evidence to support your claim. For each piece of evidence you use, explain how the evidence supports your claim.

____

____

____

____

____

____

____

____

____

____

Name: ______________________________ Date: ________________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

Scientists investigate in order to figure things out. You have been investigating what determines the appearance of the Moon from Earth, in order to tell astrophotographer Eric Wu when he can take photographs. Are you getting closer to understanding what determines the Moon's appearance?

1. I understand where the Moon gets its light. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

2. I understand why we see different phases of the Moon. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

3. I understand what causes the pattern of the Moon's phases. (check one)

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

Name: ______________________ Date: ______________

Homework: Check Your Understanding (continued)

4. I understand what happens during a lunar eclipse. (check one).

   ☐ yes

   ☐ not yet

Explain your answer choice.

____

____

5. I understand why lunar eclipses happen. (check one)

   ☐ yes

   ☐ not yet

____

____

6. What do you still wonder about what determines the Moon's appearance from Earth?

____

____

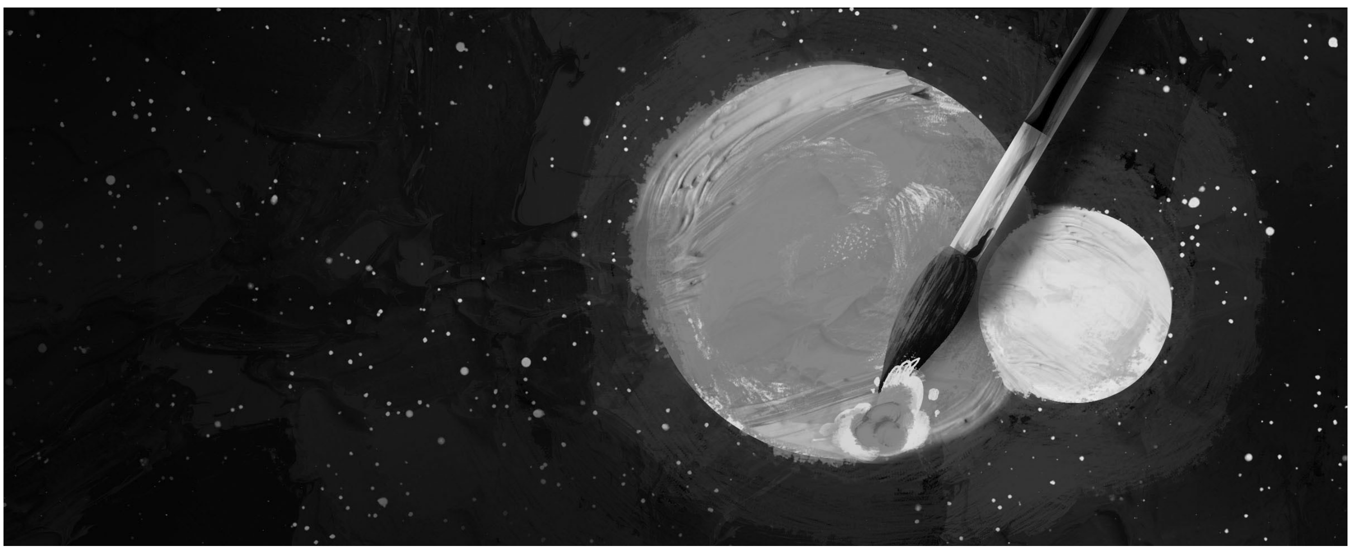
____

____

Name: ______________________ Date: ______________

Chapter 4: Science Seminar
Chapter Overview

Now that you've contributed to two articles about Earth, the Moon, and the sun, the staff at *About Space* magazine wants you to help them design some illustrations for their next issue. This time, the subject is Kepler-47c, a newly discovered planet that is outside our solar system.



Name: ______________________________ Date: ____________________

Lesson 4.1: Lunar Eclipses Outside Our Solar System

Student astronomers, your work with Eric Wu has made you a valuable contributor to *About Space* magazine. Now, your help is needed once again. The editors are planning to include an article about Kepler-47c, a newly discovered planet outside of our solar system, in a new issue. The artist in charge of illustrating this article wants to show a lunar eclipse of Kepler-47c's moon. Do lunar eclipses even happen on Kepler-47c? The staff at *About Space* has collected some information about Kepler-47c, but they need your help to figure out what it all means.

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 4 Question

- During a year, will there be a lunar eclipse of the moon of Kepler-47c?

Vocabulary

- claim
- evidence
- illuminate
- lunar eclipse
- model
- moon
- orbit
- reasoning
- scale
- scientific argument
- sun

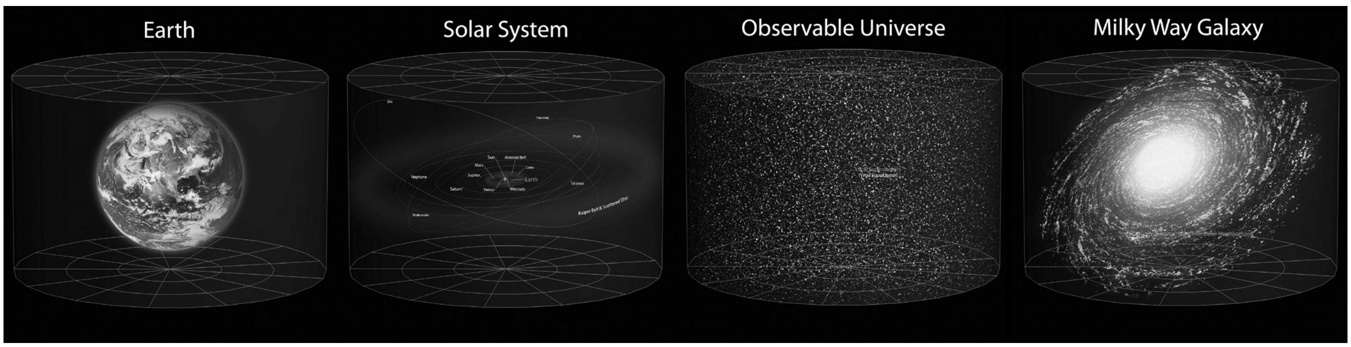
Name: ____________________ Date: ____________________

Warm-Up

Imagining Other Worlds

Our solar system is just one of many star systems in our galaxy, the Milky Way galaxy. The Milky Way galaxy is just one of many galaxies in the universe. What are other star systems and galaxies like?

Look at the images below and answer the questions. Then, share your ideas with your partner.

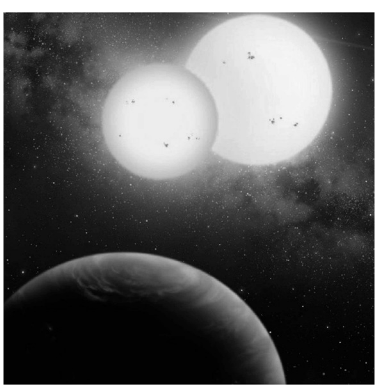


How do you think other galaxies might be similar or different from the Milky Way galaxy?

____

____

____



How is this star system different from our solar system?

____

____

____

____

____

What do you think would be different if you were on a planet in this star system?

____

____

____

Name: ______________________ Date: ______________

Analyzing Evidence

Part 1: Analyzing Evidence Card A

Examine Evidence Card A. Annotate the card to help you think about the evidence. Then, discuss the evidence with your partner, using the discussion questions below.

Discuss the following questions with your partner:

- Is a lunar eclipse of Kepler-47c's moon possible, based on this evidence?
- Is a lunar eclipse of Kepler-47c's moon likely to happen, based on this evidence?

Part 2: Drawing Lunar Eclipses

1. Read the instructions on the top of Drawing Activity: Part 1 (on page 97).
2. When you are done with Part 1, you will begin Part 2 on (page 98).
3. Be sure to discuss the Drawing Activities with your partner, using the discussion questions below as you work. When you are finished, answer the questions below.

As you work, it may be helpful to think about this key concept:

- *The Moon is only completely dark when the sun, Earth, and the Moon are in a straight line, with Earth in the middle.*

As you work on drawing the Moon's positions around Earth, discuss the following questions with your partner:

- **For Part 1:** In how many of Earth's positions is a lunar eclipse possible?
- **For Part 2:** In how many of Kepler-47c's positions is a lunar eclipse possible?

Questions

Based on this Drawing Activity, do you think a lunar eclipse of the moon of Kepler-47c is possible? (check one)

- ☐ yes
- ☐ no

Based on this Drawing Activity, which of these events do you think is most likely to happen? (check one)

- ☐ a lunar eclipse of Earth's Moon
- ☐ a lunar eclipse of Kepler-47c's moon
- ☐ both are equally likely

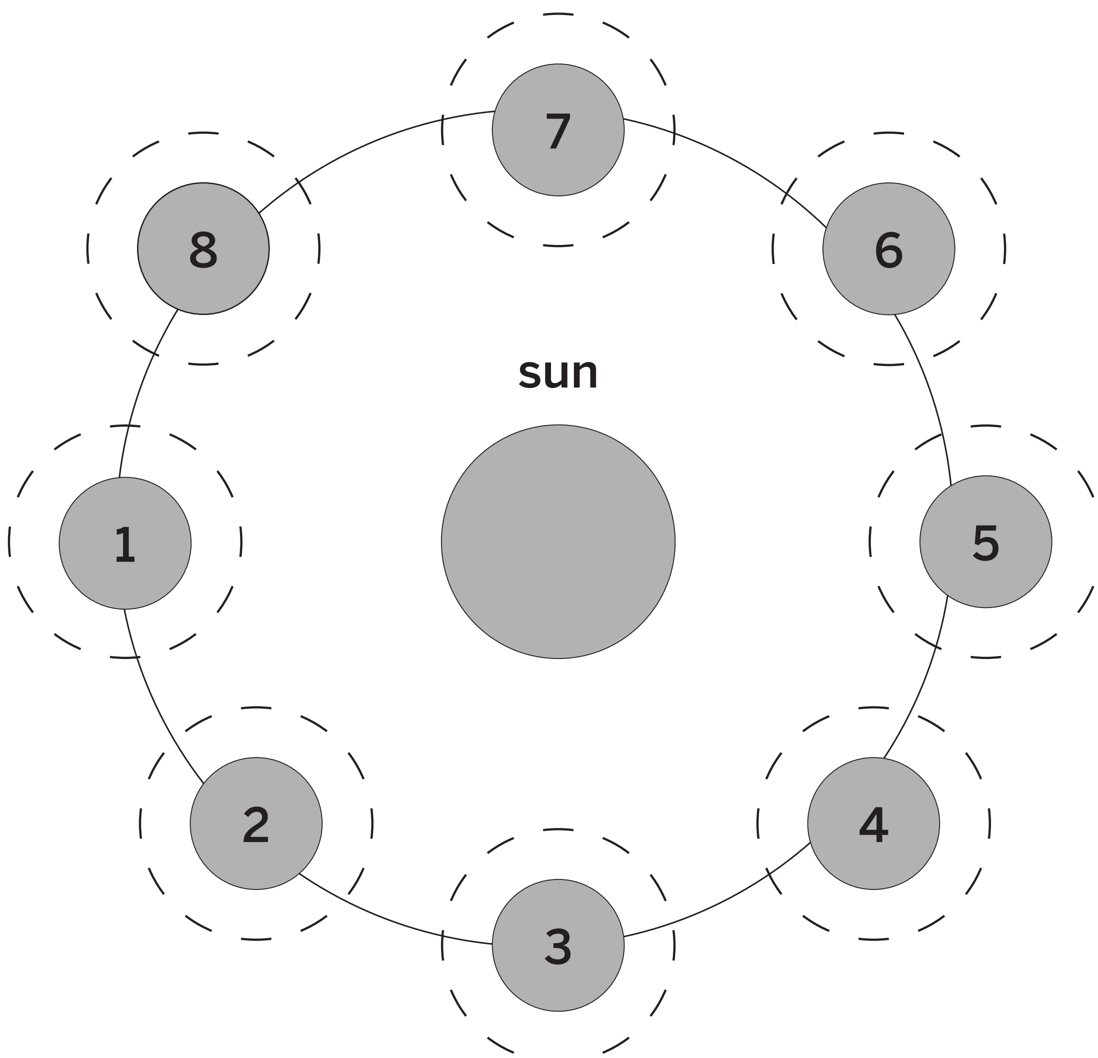
Name: ______________________ Date: ______________

Drawing Activity

Part 1: The diagram below shows Earth in eight different positions in its orbit around the sun. Around each of Earth's positions is a dashed circle representing the Moon's orbit.

1. For each of Earth's positions (1–8), try to draw the Moon in a position on the dashed circle where a lunar eclipse could happen.
2. Then, check the boxes (below the diagram) for each position in which a lunar eclipse could happen.

Note: This diagram is not to scale.



A lunar eclipse could happen when Earth is in:

- ☐ Position 1
- ☐ Position 2
- ☐ Position 3
- ☐ Position 4
- ☐ Position 5
- ☐ Position 6
- ☐ Position 7
- ☐ Position 8

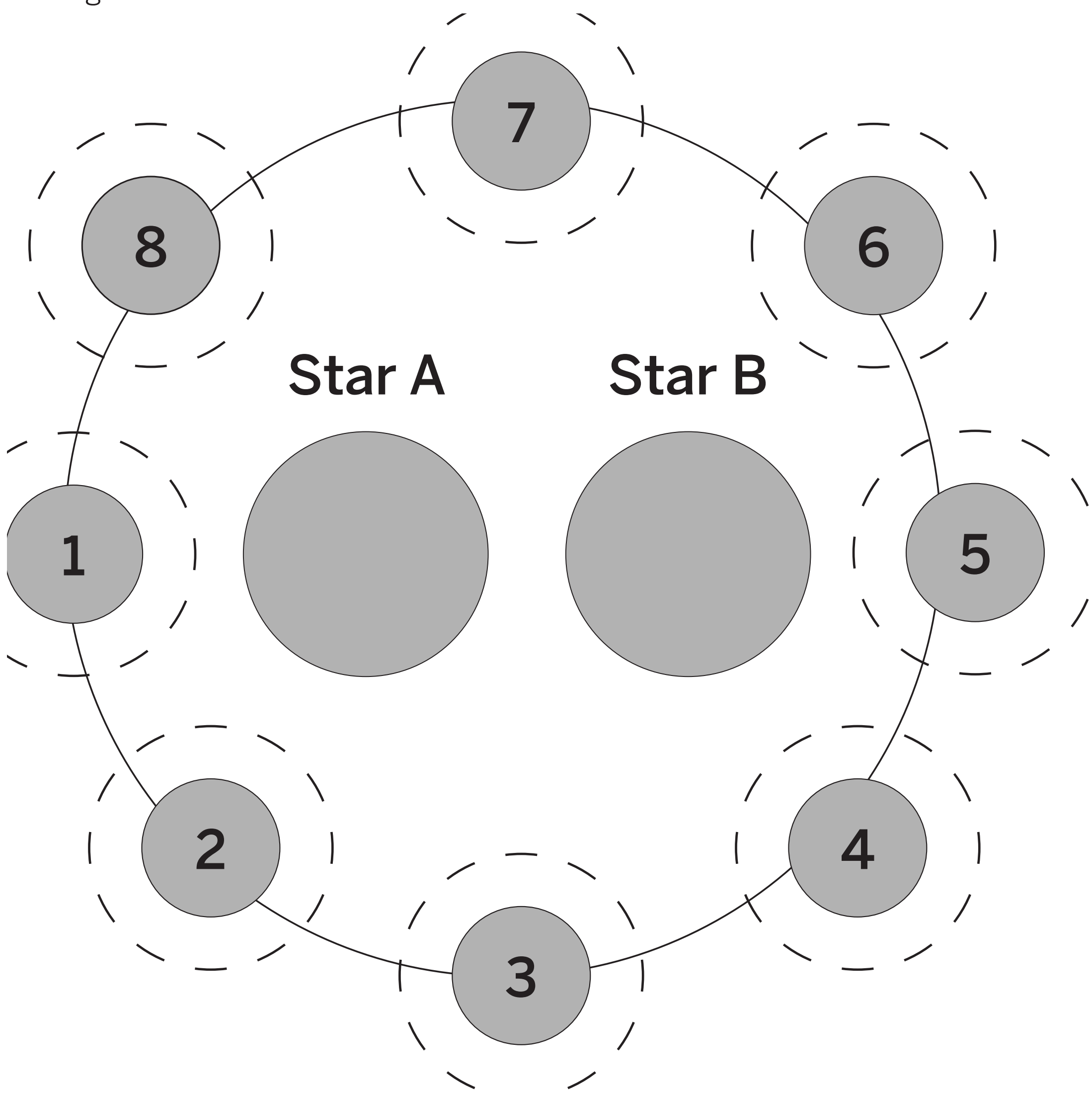
Name: ______________________ Date: ______________

Drawing Activity (continued)

Part 2: The diagram below shows Kepler-47c in eight different positions in its orbit around Stars A and B. Around each of Kepler-47c's positions is a dashed circle representing its moon's orbit.

1. For each of Kepler-47c's positions (1–8), try to draw its moon in a position on the dashed circle where a lunar eclipse could happen.
2. Then, check the boxes (below the diagram) for each position in which a lunar eclipse could happen.

Note: This diagram is not to scale.



A lunar eclipse could happen when Kepler-47c is in:

- ☐ Position 1
- ☐ Position 2
- ☐ Position 3
- ☐ Position 4
- ☐ Position 5
- ☐ Position 6
- ☐ Position 7
- ☐ Position 8

Name: ______________________ Date: ______________

Analyzing Evidence (continued)

Part 3: Analyzing Evidence Cards B and C

Examine Evidence Cards B and C. Annotate the cards to help you think about the evidence. Then, discuss the evidence with your partner, using the discussion questions below.

Discuss the following questions with your partner:

Card B: If a moon's orbit is tilted, will a lunar eclipse happen every time the planet is between the moon and the star? What if a moon's orbit is not tilted?

Card C: How does the number of moon orbits per year affect the number of lunar eclipses per year?

Name: ______________________ Date: ______________

Sorting Evidence

1. Place the Science Seminar Question at the top of your desk.
2. Place the two claims, side by side, underneath the question.
3. With a partner, discuss whether each piece of evidence supports or goes against the claims. Use the sentence starters below to help you discuss this with your partner.
4. Make annotations on each card.
   - If the evidence supports a claim, write “supports Claim 1 or 2” on that card.
   - If the evidence goes against a claim, write “goes against Claim 1 or 2” on that card.
   - If the evidence connects with another evidence card, write “connects with Evidence Card A, B, or C” on that card.
5. Sort the evidence by placing the cards under the claim they support.

Sentence Starters

I think this piece of information supports this claim because . . .

I don’t think this piece of information supports this claim because . . .

I agree because . . .

I disagree because . . .

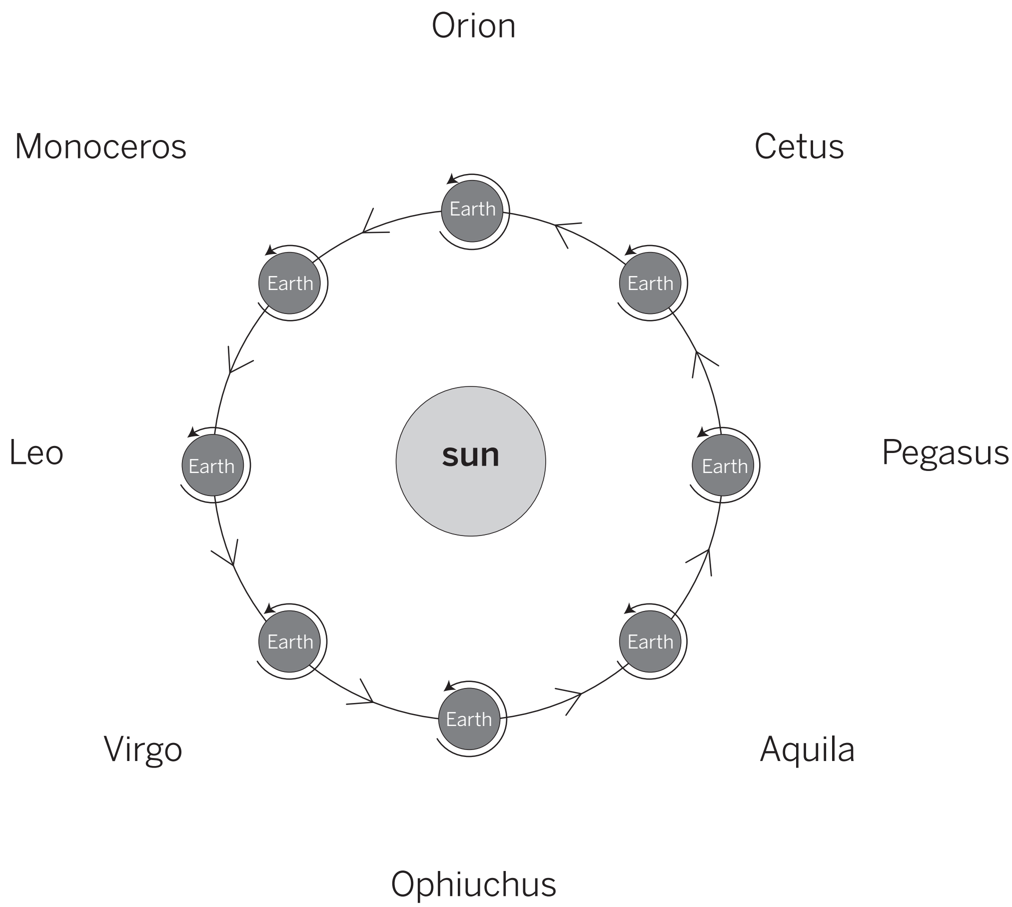
Why do you think that?

Name: ______________________________ Date: ________________

Homework: Why the Stars Seem to Move

The diagram below shows how Earth rotates and how Earth orbits around the sun, as well as the names of eight constellations, each in a different direction from the sun. Use the diagram to help you answer the questions below.

Note: This diagram is not to scale.



Why do the stars seem to rise and set each day?

____

____

____

Why do we see different constellations at different times of year?

____

____

____

Name: ____________________ Date: ____________

Lesson 4.2: Discussing Eclipses in a Two-Star System

Will there be a lunar eclipse of the moon of Kepler-47c? Today, you'll discuss this question, using what you know about lunar eclipses in the Earth, Moon, and sun system and the evidence about Kepler-47c to build an argument. Are lunar eclipses possible in a two-star system? Are they likely? It's now time to make your case, student astronomers!

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 4 Question

- During a year, will there be a lunar eclipse of the moon of Kepler-47c?

Key Concepts

- The Moon does not make its own light; the sun illuminates the Moon.
- When a model is "to scale," object sizes and distances are larger or smaller than in the real world but the same relative to one another. Some models need to be "not to scale" to be useful.
- The sun illuminates the half of the Moon that is facing it, and the other half is dark.
- Light from the sun travels in straight lines.
- From Earth we can only see the half of the Moon that is facing us.
- Because the Moon moves to different positions around Earth, we see different amounts of the illuminated half of the Moon. This is why we see different phases of the Moon.
- There is a pattern to the position of the Moon because the Moon orbits around Earth.
- It takes about one month for the Moon to orbit Earth, so it takes about one month to see the full pattern of moon phases. This pattern repeats with every orbit of the Moon.
- During a lunar eclipse, the Moon is completely dark because Earth blocks sunlight from hitting the Moon.
- Lunar eclipses can only happen when Earth is in between the sun and the Moon.
- Lunar eclipses do not happen every time Earth is in between the sun and the Moon.
- The Moon is only completely dark when the sun, Earth, and the Moon are in a straight line, with Earth in the middle.

Name: ______________________ Date: ______________

Lesson 4.2: Discussing Eclipses in a Two-Star System (continued)

Vocabulary

- claim
- evidence
- illuminate
- lunar eclipse
- model
- moon
- orbit
- reasoning
- scale
- scientific argument
- sun

Name: ______________________ Date: ______________

Warm-Up

Revisiting the Evidence

Review your sorted Science Seminar Evidence cards from the previous lesson. Then, use the evidence cards to answer the questions below.

Which claim do you think is the most convincing? (check one)

- ☐ **Claim 1:** Yes, there probably will be a lunar eclipse.
- ☐ **Claim 2:** No, there probably won't be a lunar eclipse.

Draw a star on the evidence card that best supports your claim. Why did you choose this piece of evidence?

____

____

____

____

Name: ______________________________ Date: ____________________

Preparing a Science Seminar Argument

1. With your partner, take turns sharing which claim you think is the most convincing.
2. Use your Warm-Up responses and the Argumentation Sentence Starters to help you share ideas.
3. Refer to the Science Seminar Evidence cards as needed.

During a year, will there be a lunar eclipse of the moon of Kepler-47c? (check one)

☐ **Claim 1:** Yes, there probably will be a lunar eclipse.

☐ **Claim 2:** No, there probably won't be a lunar eclipse.

Argumentation Sentence Starters

- I think this evidence supports this claim because . .
- I don't think this evidence supports this claim because . .
- I agree because . .
- I disagree because . .
- Why do you think that?

Name: ______________________________ Date: ____________________

Science Seminar Observations

Write a check mark in the right-hand column every time you hear one of your peers say or do something listed in the left-hand column. If you hear an interesting idea, write it in the last row of the table.

Observations during the seminar	**Check marks**
I heard a student use evidence to support a claim.	
I heard a student respectfully disagree with someone else's thinking.	
I heard a student explain how her evidence is connected to her claim.	
I heard a student evaluate the quality of evidence.	
I heard an idea that makes me better understand one of the claims. That idea is:	

Name: ______________________________ Date: ______________

Homework: Reflecting on the Science Seminar

Now that the Science Seminar is over, think back on the claim you selected at the beginning of the lesson. After participating in the discussion, you may have changed your mind about which claim you think is best supported. Show your current thinking by answering the questions below.

Which claim do you now think is the most convincing? (check one)

- ☐ **Claim 1:** Yes, there probably will be a lunar eclipse.
- ☐ **Claim 2:** No, there probably won't be a lunar eclipse.

Did the Science Seminar cause your thinking about the claims to change? Explain your answer.

____

____

____

____

____

____

Name: ______________________________ Date: ________________

Lesson 4.3: Writing a Scientific Argument

Student astronomers, you've discussed the claims and the evidence about Kepler-47c and its moon. Now, it's time for you to make your case in writing. Today, you'll review the evidence and use the Reasoning Tool to organize your thinking. Then, you'll write a scientific argument to Amasha Oda, the artist at *About Space* magazine, stating whether you think there will be a lunar eclipse of Kepler-47c's moon. Get ready to defend your claim, student astronomers!

Unit Question

- What determines the appearance of the Moon from Earth?

Chapter 4 Question

- During a year, will there be a lunar eclipse of the moon of Kepler-47c?

Key Concepts

- The Moon does not make its own light; the sun illuminates the Moon.
- When a model is "to scale," object sizes and distances are larger or smaller than in the real world but the same relative to one another. Some models need to be "not to scale" to be useful.
- The sun illuminates the half of the Moon that is facing it, and the other half is dark.
- Light from the sun travels in straight lines.
- From Earth we can only see the half of the Moon that is facing us.
- Because the Moon moves to different positions around Earth, we see different amounts of the illuminated half of the Moon. This is why we see different phases of the Moon.
- There is a pattern to the position of the Moon because the Moon orbits around Earth.
- It takes about one month for the Moon to orbit Earth, so it takes about one month to see the full pattern of moon phases. This pattern repeats with every orbit of the Moon.
- During a lunar eclipse, the Moon is completely dark because Earth blocks sunlight from hitting the Moon.
- Lunar eclipses can only happen when Earth is in between the sun and the Moon.
- Lunar eclipses do not happen every time Earth is in between the sun and the Moon.
- The Moon is only completely dark when the sun, Earth, and the Moon are in a straight line, with Earth in the middle.

Name: ______________________________ Date: ____________________

Lesson 4.3: Writing a Scientific Argument (continued)

Vocabulary

- claim
- evidence
- illuminate
- lunar eclipse
- model
- moon
- orbit
- reasoning
- scale
- scientific argument
- sun

Name: ____________________ Date: ____________

Warm-Up

Dina and Calais are two students studying about Earth, the Moon, and the sun at another school. Dina and Calais both used the Reasoning Tool to make their own arguments about why we see moon phases. As you read and compare these two arguments, pay close attention to the middle column. Then, answer the questions on the next page.

Dina's argument

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
When the Moon moves in Top View in the Sim, we see different moon phases in the View from Earth.	What we see depends on the position of the Moon. This position determines how much of the illuminated half of the Moon we can see from Earth.	We see moon phases because the Moon moves around Earth.

Calais's argument

Evidence	**This matters because . . .** (How does this evidence support the claim?)	**Therefore, . . .** (claim)
When the Moon moves in Top View in the Sim, we see different moon phases in the View from Earth.	The different phases of the Moon that we can see are new moon, crescent moon, quarter moon, gibbous moon, and full moon.	We see moon phases because the Moon moves around Earth.

Name: ______________________________ Date: ________________

Warm-Up (continued)

Which argument is more convincing? (check one)

- ☐ Dina's argument
- ☐ Calais's argument

What makes one argument more convincing than the other?

____

____

____

____

____

____

Name: ____________________ Date: ____________________

Using the Reasoning Tool to Support Your Claim

Why is reasoning important?

After scientists state a claim, they connect evidence to the claim in the reasoning process. **This makes their argument convincing.**

Use the Science Seminar Reasoning Tool sheet to explain how the evidence supports your claim. Follow the instructions below.

1. Record the claim that you think is best supported by the evidence (in the **Therefore, . . .** column). If you prefer, you can also write and record your own claim.
2. Tape the evidence cards that support your claim to the Reasoning Tool (in the **Evidence** column). You do not need to use all the cards, but you can use more than one to support your claim.
3. Use the middle column (**This matters because . . .**) to record how the evidence in the left column connects to the claim in the right column.

Name: ______________________________ Date: ____________________

Organizing Ideas in the Reasoning Tool

Plan how you will use your completed Reasoning Tool to write your argument. Use the example below to guide you.

- Draw a circle around your strongest piece of evidence.
- Draw an X over a piece of evidence if you do not plan to use it in your argument.
- Draw an arrow to connect two pieces of evidence if you think that they go together.

Example

Evidence	This matters because . . . (How does this evidence support the claim?)	Therefore, . . . (claim)
Example Evidence Card A	Your ideas about how the evidence supports the claim	Your claim
Example Evidence Card B	Your ideas about how the evidence supports the claim	
Example Evidence Card C	Your ideas about how the evidence supports the claim	

Name: ______________________________ Date: ____________________

Writing a Scientific Argument

Write your scientific argument on the next page to the artist at *About Space* magazine. As you write, remember to:

- Review your Reasoning Tool. Be sure to include your strongest piece of evidence and to make a connection between pieces of evidence that go together.
- Use the Argumentation Sentence Starters to help you explain your thinking.

Argumentation Sentence Starters

- I think this evidence supports this claim because . .
- I don't think this evidence supports this claim because . .
- I agree because . .
- I disagree because . .
- Why do you think that?

Write a scientific argument that addresses the question: *During a year, will there be a lunar eclipse of the moon of Kepler-47c?*

- First, state your claim.

  Claim 1: Yes, there probably will be a lunar eclipse.

  Claim 2: No, there probably won't be a lunar eclipse.
- Then, use evidence to support your claim.
- For each piece of evidence you use, explain how it supports your claim.

Name: ____________________ Date: ____________

Writing a Scientific Argument (continued)

Name: ______________________ Date: ______________

Homework: Revising an Argument

1. Reread the scientific argument you wrote in class. Complete your argument, if needed.
2. Then, look for ways you could make your argument clearer or more convincing.
3. Consider reading your argument aloud or having another person read it.
4. Use the questions below to help you review your argument:
   - Does your argument clearly explain why there might or might not be a lunar eclipse?
   - Do you describe your supporting evidence?
   - Do you thoroughly explain how the evidence supports your claim?
5. Rewrite any sections of your argument that could be clearer or more convincing.

Name: ____________________ Date: ____________________

Homework: Revising an Argument (continued)

Name: ______________________ Date: ______________

Homework: Check Your Understanding

This is a chance for you to reflect on your learning so far. This is not a test. Be open and truthful when you respond to the questions below.

1. I understand that scientists connect evidence to their claims to make stronger arguments.

   ☐ yes

   ☐ not yet

Explain your answer choice.

___

___

___

___

2. What are the most important things you have learned in this unit about what determines the appearance of the Moon from Earth?

___

___

___

___

___

___

3. What questions do you still have?

___

___

___

___

___

___

Earth, Moon, and Sun Glossary

crescent moon: a moon phase that looks like less than half a circle from Earth

luna creciente: una fase lunar que se ve como menos de la mitad de un círculo desde la Tierra

exomoon: a moon outside our solar system

exoluna: una luna que se encuentra fuera de nuestro sistema solar

exoplanet: a planet outside our solar system

exoplaneta: un planeta que se encuentra fuera de nuestro sistema solar

full moon: a moon phase that looks like a full circle from Earth

luna llena: una fase lunar que se ve como un círculo completo desde la Tierra

gibbous moon: a moon phase that looks like more than half a circle from Earth

luna gibosa: una fase lunar que se ve como más de la mitad de un círculo desde la Tierra

illuminate: to shine light on an object and make it visible

iluminar: arrojar luz sobre un objeto y hacerlo visible

lunar eclipse: when the Moon is completely dark

eclipse lunar: cuando la Luna está completamente oscura

model: an object, diagram, or computer program that helps us understand something by making it simpler or easier to see

modelo: un objeto, diagrama o programa de computadora que nos ayuda a entender algo haciéndolo más simple o fácil de ver

moon: a rocky sphere that travels around a planet

luna: una esfera rocosa que viaja alrededor de un planeta

moon phase: the shape of the illuminated part of the Moon as it appears from Earth

fase lunar: la forma de la parte iluminada de la Luna tal como se ve desde la Tierra

new moon: a moon phase in which the Moon is not visible from Earth

luna nueva: una fase lunar en la que la Luna no es visible desde la Tierra

Earth, Moon, and Sun Glossary (continued)

orbit: the nearly circular path a smaller object (like the Moon) travels around a larger object (like Earth)

órbita: la ruta casi circular por la que un objeto más pequeño (como la Luna) viaja alrededor de un objeto más grande (como la Tierra)

pattern: something we observe to be similar over and over again

patrón: algo que observamos que sea similar una y otra vez

quarter moon: a moon phase that looks like a half-circle from Earth

cuarto de luna: una fase lunar que se ve como la mitad de un círculo desde la Tierra

scale: the relative size of things

escala: el tamaño relativo de las cosas

solar system: the sun, the planets that orbit the sun, and other objects that orbit the sun

sistema solar: el sol, los planetas que orbitan el sol y otros objetos que orbitan el sol

sun: the star that is the main source of light at the center of our solar system

sol: la estrella que es la fuente principal de luz en el centro de nuestro sistema solar

terminator: the border between light and dark on the Moon

terminador: la frontera entre la luz y la oscuridad sobre la Luna

year: the amount of time it takes for a planet to complete one orbit around a star or stars

año: la cantidad de tiempo que tarda un planeta en completar una órbita alrededor de una estrella o estrellas

Lawrence Hall of Science:
Program Directors: Jacqueline Barber and P. David Pearson
Curriculum Director, Grades K–1: Alison K. Billman
Curriculum Director, Grades 2–5: Jennifer Tilson
Curriculum Director, Grades 6–8: Suzanna Loper
Assessment and Analytics Director: Eric Greenwald
Learning Progressions and Coherence Lead: Lauren Mayumi Brodsky
Operations and Project Director: Cameron Kate Yahr
Student Apps Director: Ari Krakowski
Student Content Director: Ashley Chase

Leadership Team: Jonathan Curley, Ania Driscoll-Lind, Andrew Falk, Megan Goss, Ryan Montgomery, Padraig Nash, Kathryn Chong Quigley, Carissa Romano, Elizabeth Shafer, Traci K. Shields, Jane Strohm

***Earth, Moon, and Sun: An Astrophotographer's Challenge* Unit Team:**

Jennifer Arter
Stacy Au-yang
Elizabeth Ball
Maggie Ballard
Lee M. Bishop
Candice Bradley
Benton Cheung
Sybil Lockhart
Deirdre MacMillan
Christina Morales
Natalie Roman
Joshua A. Willis
Lizzy Vlasses

Amplify:

Irene Chan
Samuel Crane
Shira Kronzon
Charvi Magdaong
Thomas Maher
Rick Martin
Matt Reed
Eve Silberman
Steven Zavari

Credits:
Illustration: Cover: Tory Novikova
Photographs: Pages 6 (l), 56: NASA; Pages 6 (r), 10 (soccer field), 14, 18, 23, 27: Shutterstock; Page 58: NASA; Page 95: NASA/Lynette Cook

Earth, Moon, and Sun:
An Astrophotographer's Challenge

Article Compilation

Table of Contents: Articles

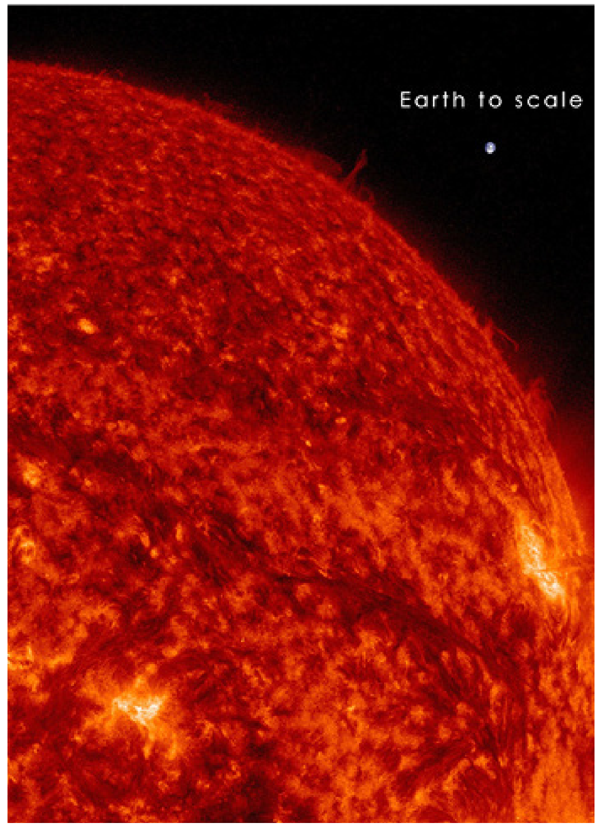
The Solar System Is Huge

When people think of our solar system, they think of the sun, planets, moons, comets, and other objects. Actually, the solar system is mostly empty space. The biggest object in the solar system is the sun. The diameter of the sun is 1,400,000 (1.4 million) kilometers. In comparison, about 58,000,000 (58 million) km of empty space separate the sun from its closest planet, Mercury. The whole solar system takes up a vast area of space: it's about 9,000,000,000 (9 billion) km in diameter. That's more than 6,000 times wider than the sun! As big as it is, the sun is tiny in scale compared to the scale of the empty spaces in the solar system.

All the other objects in the solar system fill up even less of this empty space. Imagine gathering all eight planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune) and all their moons, plus all the asteroids, comets, and other objects in the solar system. Even added all together, these objects aren't as big as the sun. Compared to all the empty space in the solar system, the objects in it are very small in scale.

Since the solar system is so big and the objects in it are so small in comparison, making a model of the solar system can be difficult. Most solar system models can either show the sizes of the different objects in the solar system or the distances between them. If the sizes and the distances were both shown accurately, the model would not fit on a page or a computer screen!

To address this problem, scientists use two different types of models: models that are to scale and models that are not to scale.



This image shows the size of the sun compared to the size of Earth. The sun is many times bigger than any of the planets, but it is still tiny in scale compared to the whole solar system.

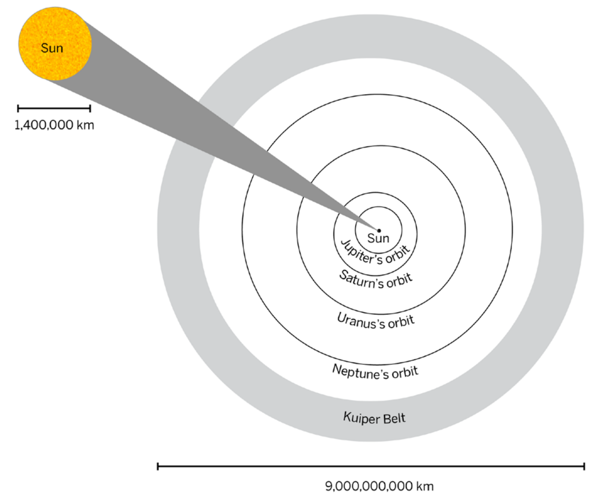
In models that are to scale, everything—the sizes of the objects and the distances between them—has been shrunk or enlarged by the same percentage. Because of that, you can use scale models to compare size relationships. In models that are not to scale, the sizes of the objects and the distances between them may not have been changed by the same percentage. You can learn many things from models that are not to scale, but you can't necessarily use them to compare the size of objects or the distances between them.

Both kinds of models can be useful, depending on what the model is for. Models that are to scale are most useful for showing the relationships between the sizes of things and the distances between them. The model at the top of page 2 is to scale. It shows the sizes of the orbits of the four outer planets of the solar system and gives you an idea of how far apart they are. However, because the outer planets' orbits are so large and so far away from the sun, this model can't show things that are smaller in scale. For example, you can't see any of the actual planets, just the paths of their orbits. The model doesn't even show the orbits of the inner planets, such as Earth—they're too small. Even the sun itself, which is very large, has to be magnified in order to be visible in this scale model!

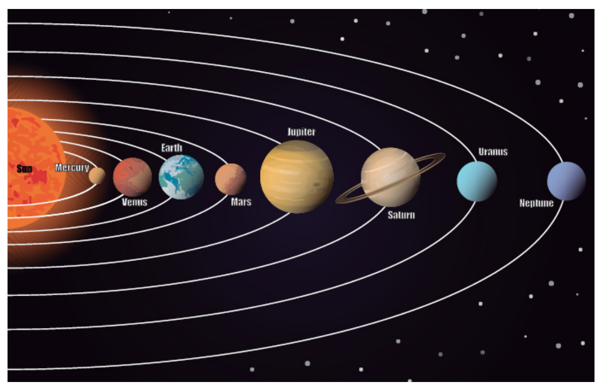
Models that are NOT to scale can still be useful. Models that are not to scale are most useful when seeing size and distance relationships isn't as important. If you wanted a model that included all the objects in the solar system, but didn't need it to show how far apart they are, a model that is not to scale would work well. The model to the lower right is not to scale. It doesn't give a good idea of the relative sizes of the planets and how far apart they are, but it does include all eight planets and the sun, and the order the planets are in relative to the sun. In many cases, scientists use models that are not to scale to get their ideas across.

As you can see, it is possible for a model to show the size of the solar system or the sizes of the planets inside it, but a model that showed both to scale at the same time would be so large that it wouldn't be useful at all.

Solar System



In this diagram of the solar system, the orbits of Earth, Mercury, Venus, and Mars are too small to see. Compared to the whole solar system, they are very close to the sun.

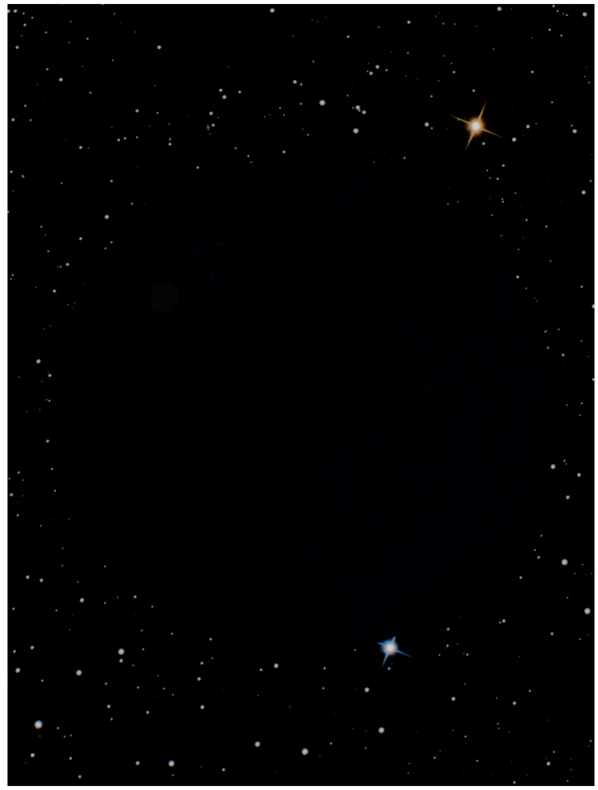


This diagram shows the sun and planets in our solar system. The diagram is not to scale.

The Dark Side of the Moon

In 1968, as part of NASA's Apollo 8 mission, astronauts from the United States became the first humans to travel all the way around the Moon in a spacecraft. When they were flying by the half of the Moon that was facing the sun, they could see the Moon well—the direct light of the sun made everything visible. But when they were flying by the half of the Moon that was facing away from the sun, they could see very little. Without light from the sun, the surface of the Moon was so dark that the astronauts couldn't see it, even though it was large and they were flying near it. The Moon was so dark that the astronauts could only see a circle of darkness blocking the stars.

How can one side of the Moon be so bright and the other so dark? It's because the Moon does not make its own light. The moonlight you see from Earth is actually light from the sun. The sun is the main source of light in our solar system. Light from the sun travels in a straight line, so the sun can only illuminate the side of the Moon that's facing it. The side of the Moon that faces the sun is very bright. The side of the Moon that faces away from the sun, however, is in almost complete darkness. A small amount of light travels into our solar system from other stars, but because the stars are so far away, it isn't much.



When the astronauts on the Apollo 8 mission flew by the side of the Moon that was not illuminated by the sun, it was so dark that they couldn't see the Moon. They could only see an area where the stars were blocked.

Which side of the Moon is the bright side and which is the dark side? It depends. As Earth and the Moon move through space, different parts of the Moon move into the path of the sun's light—so half of the Moon is always illuminated by the sun, but it isn't always the same half. Every part of the Moon is sometimes illuminated by the sun and sometimes in almost total darkness.

The sun illuminates the half of the Moon that faces it, leaving the other half in darkness.

Phases of the Moon

Have you ever looked at the Moon and seen a face looking back at you? So have lots of other people—many cultures have myths about a face or other shapes on the surface of the Moon. Of course, the face on the Moon isn't really a face. It's an arrangement of large flat areas called *maria* (that's Latin for seas, because early astronomers thought these areas were oceans) that were formed by volcanic eruptions. Whether the *maria* look like a face or something else to you, they are always facing Earth, even when they aren't illuminated by light from the sun. The side of the Moon that faces Earth is always the same.

However, that doesn't mean that the Moon always looks the same when we see it in the sky. When we look up at the Moon, what we see depends on where the Moon is in its orbit, the nearly circular path that it travels around Earth. You may know that the sun always illuminates half of the Moon, but because the Moon is constantly moving and changing position along its orbit, the half of the Moon that faces the sun doesn't always face toward Earth. As the Moon moves around Earth, different parts of the Moon are illuminated by the sun. This makes the Moon look different from night to night. These changes in the Moon's appearance are called the phases of the Moon, and you've probably seen them before. In the sections below, you'll read about five phases of the Moon: the new moon, the crescent moon, the quarter moon, the gibbous moon, and the full moon.

The photograph above shows a full moon as seen from Earth.

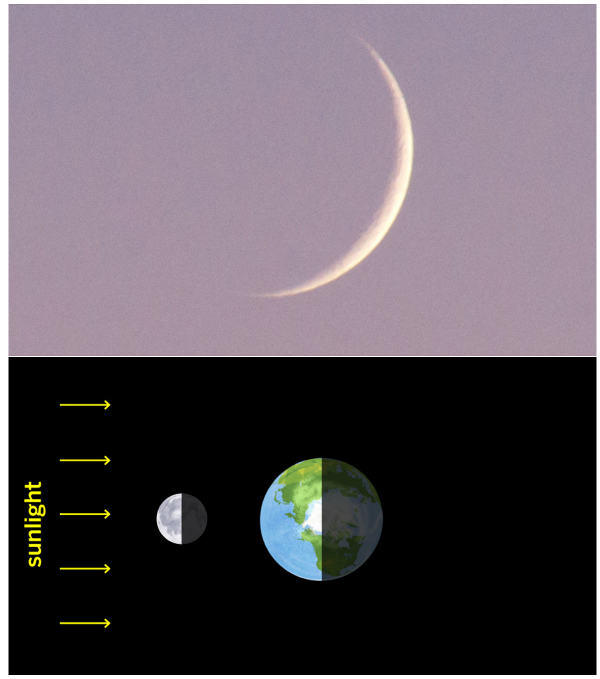
The photograph above shows a crescent moon as seen from Earth.

New Moon

Sometimes, it's hard to see the Moon from Earth at all. When the side of the Moon that faces Earth doesn't get any light from the sun, we call it a new moon. During a new moon, the Moon is between Earth and the sun. As always, the sun illuminates half the Moon—but during a new moon, the half that's illuminated is the half that faces away from Earth. Therefore, the side of the Moon that faces Earth is dark during a new moon.

The exact moment of a new moon, when the Earth-facing side of the Moon isn't illuminated by the sun at all, always happens during the day. The new moon is not easily visible from Earth because the side of the Moon that faces us is dark at the same time that the sky is bright with daylight. This is because the Moon and the sun are always on the same side of Earth during a new moon.

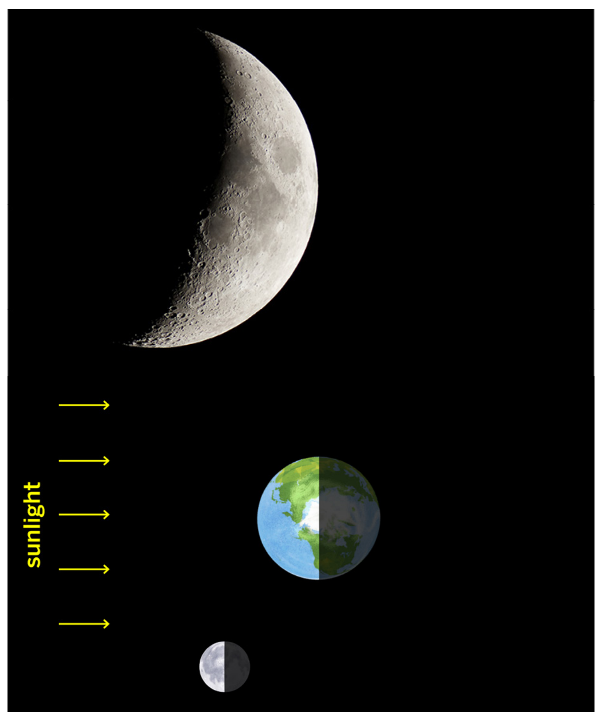
Many cultures use calendars that are based on the phases of the Moon. Those calendars often use the new moon to mark the beginning of each month.



The photograph above shows the Moon just after the new moon phase, when it first becomes visible again. The diagram below it shows the position of the Moon during a new moon phase.

Crescent Moon

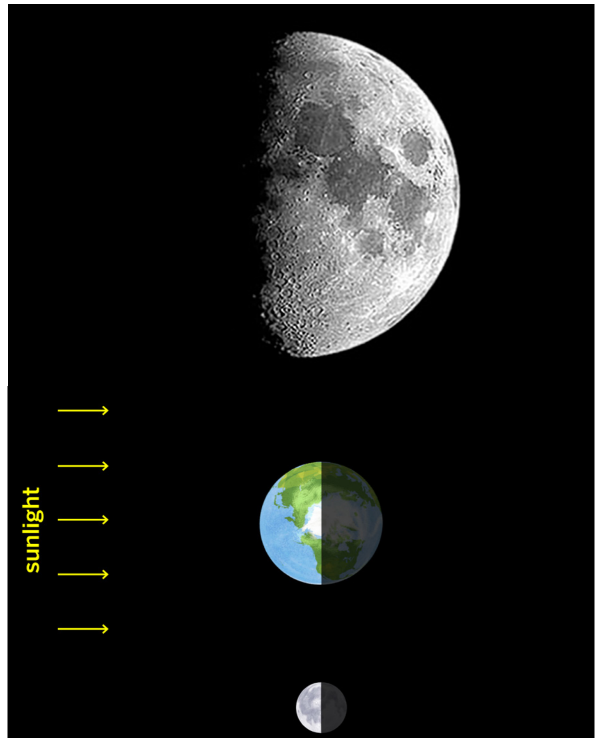
During the crescent moon phase, only a small section of the part of the Moon that faces Earth is illuminated. Half of the Moon is still illuminated by the sun, but we only see a small part of the illuminated portion. This means we see the Moon as a small sliver, or crescent.



The photograph above shows a crescent moon as seen from Earth. The diagram below it shows one position the Moon can be in during a crescent moon phase.

Quarter Moon

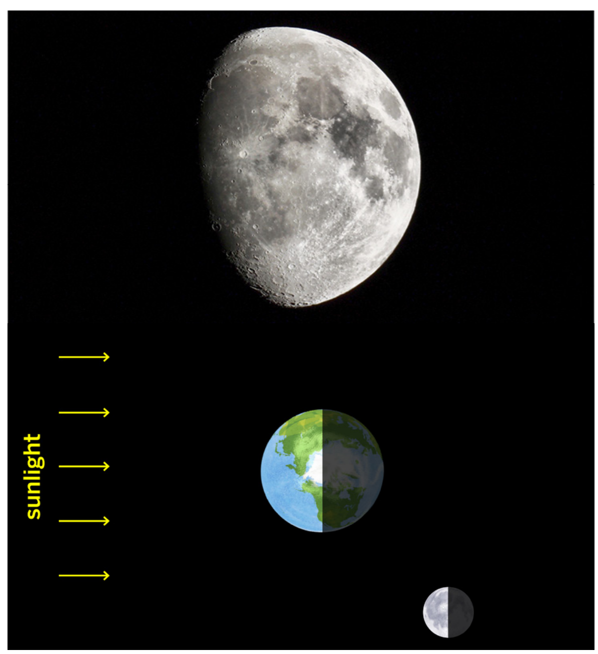
In the quarter moon phase, the Moon looks like a half-circle from Earth. Half of the side that faces Earth is in sunlight, and half is in darkness. Just as always, sunlight illuminates the half of the Moon that faces toward the sun, and from Earth we see half of that illuminated half. Half of a half is a quarter, and that's why this phase is called a "quarter moon."



The photograph above shows a quarter moon as seen from Earth. The diagram below it shows one position the Moon can be in during a quarter moon phase.

Gibbous Moon

During a gibbous moon phase, the side of the Moon facing Earth is almost, but not quite, completely illuminated. Half of the Moon is still illuminated by the sun, and we see almost all of the illuminated half.

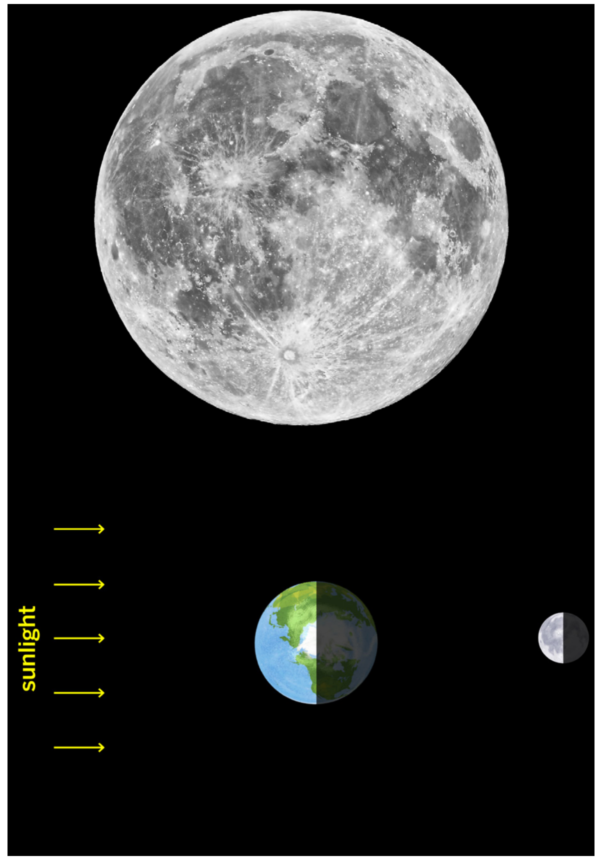


The photograph above shows a gibbous moon as seen from Earth. The diagram below it shows one position the Moon can be in during a gibbous moon phase.

Full Moon

During a full moon, the Moon is on the opposite side of Earth from the sun. As always, the sun illuminates half of the Moon—and during a full moon, the side that's being lit is the side we see! That also means the side of the Moon we don't see is totally dark during a full moon. During a full moon, the entire side of the Moon that faces Earth is illuminated and easy to see.

No matter what phase the Moon is in, one thing is the same: half of the Moon is illuminated by the sun. What changes from night to night is how much of that half we can see from Earth. When the entire illuminated half of the Moon is facing Earth, we see a full circle of light, which we call a full moon. Then, as the Moon continues in its orbit around Earth, we see less and less of it until the illuminated half is facing directly away from Earth, and it seems to disappear. This happens when the illuminated half faces entirely away from Earth, and we call this a new moon. But don't worry—the Moon is never out of sight for very long. As its orbit around Earth continues, the illuminated half of the Moon moves back into our view—just a little at first, but more and more each night until, about a month after the last full moon, it is finally full again.



The photograph above shows a full moon as seen from Earth. The diagram below it shows the position of the Moon during a full moon phase.

Meet a Scientist Who Studies the Early Solar System

Kaveh Pahlevan is an astronomy researcher in France.

Astronomer Kaveh Pahlevan studies Earth, the Moon, and the sun, but his goal isn't to learn about how they are today. Instead, he's trying to find out what they were like long, long ago—so long ago that our solar system had not yet formed. "There was a time before the sun, the Moon, and Earth and other planets even existed," says Pahlevan. "In my work, I look at what these objects look like today and try to use clues to figure out how they came to be the way they are."

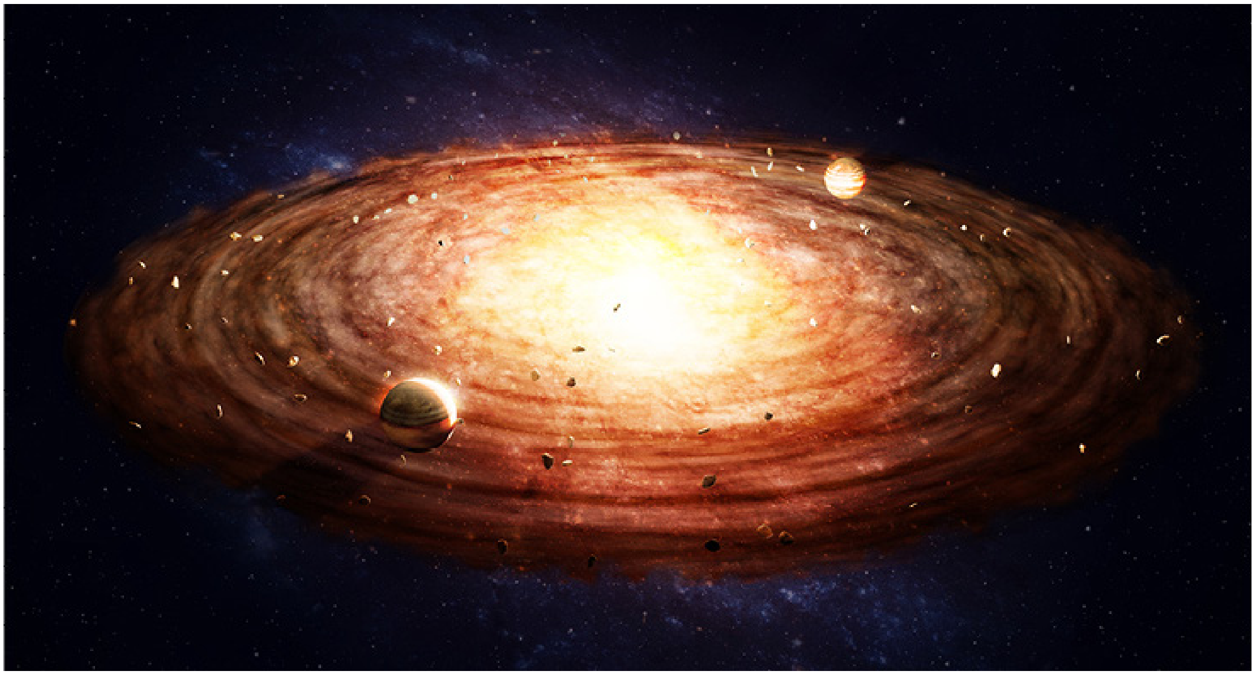
"Scientists are pretty sure that the Moon formed in a collision between Earth and another planet, but the details of that collision are not well known," he says. Pahlevan is trying to answer questions like how large the planet was that crashed into Earth and how fast it was going before the crash. How can scientists get evidence about something that happened so long ago? There are many different ways of gathering this kind of evidence. Some scientists use computer models to help them figure out what happened. Pahlevan looks for clues from the objects themselves using rocks collected by astronauts during trips to the Moon. "I am working to relate some of these scenarios to something that we can measure in the Moon rocks returned by the astronauts," he says. Together, evidence from this kind of hands-on observation and evidence from computer models can help scientists understand what happened during the collision that formed the Moon.

Pahlevan looks for clues that can tell him how the Moon formed.

It's not surprising to Pahlevan that he became a scientist—he's always been interested in the natural world. "As a child, I had a 'science box' where I would collect rocks, feathers, and eggshells that were worthy of collection," he says. In school, his teachers introduced him to the formal study of science: how to ask and investigate questions. And then, in college, he found the subject that would be his career. "I took an introductory course on astronomy, and I immediately knew that I wanted to be in this world," he says. "Scientists had discovered that the sun was an ordinary star, that the atoms in our bodies were forged inside of dying stars?! I had to be a part of this." Today he works as a researcher at an observatory (a place where telescopes are used to observe objects in space) in Nice (NEES), a city in southern France.

To Pahlevan, being a scientist is exciting because he can learn things that are new to him—and things that are new to everybody. "As a researcher, you are always learning new things about the universe that you didn't know before, and sometimes learning new things that no one has ever known," he says.

However, Pahlevan says he doesn't spend all his time doing experiments and making exciting discoveries. Designing and preparing experiments, analyzing and communicating what he's learned, writing reports, and working with other scientists can be a lot of work! "Doing the research and making discoveries is the fun part," he says. "But as a researcher, you also have to write up and publish your work in scientific articles to get credit for them, and to share your results with other researchers. This is an arduous and time-consuming process, which can be a challenge, especially if you're already thinking about the next discovery." Still, it's all worth it. "When you make a new discovery, you are the first person to know something," he says. "There's a certain quiet exhilaration in that."



Our solar system formed billions of years ago from a huge disk of dust and gases. This illustration shows what the early solar system may have looked like.

Gravity in the Solar System

Have you ever wondered where our solar system—the sun, the planets, and all the other objects nearby—came from? Here's a hint: the same force that keeps you close to Earth's surface also began the process that formed the solar system. Gravity, or gravitational force, is an attractive force between all objects that have mass. The more mass an object has, the more strongly it pulls other objects toward it through the force of gravity. So how did this force help produce the sun and all the objects that move around it?

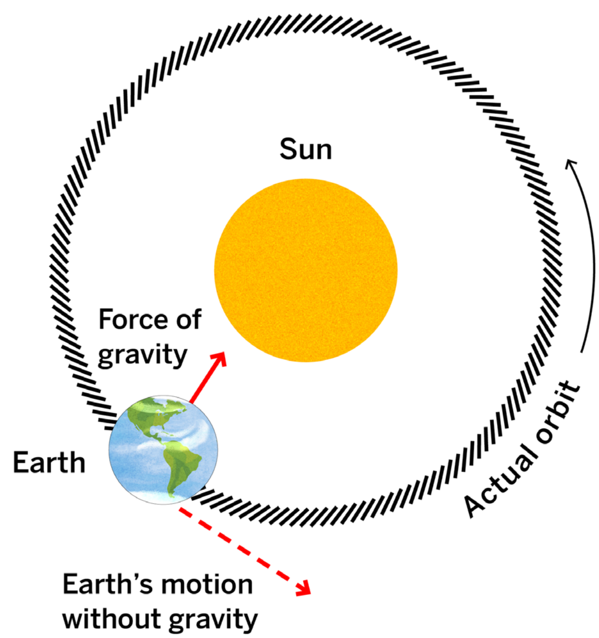
About 4.6 billion years ago, our area of space was a huge cloud of dust and gases. Then something changed: a small part of the cloud collapsed in on itself. The collapse brought many particles in that area of the cloud very close together. In other words, many particles with tiny masses stuck together to form one big clump with a lot of mass. Since a lot of mass means a lot of gravitational force, that area began to attract more and more particles from the cloud and got bigger and bigger. As this cloud collapsed, the whole thing began to rotate around its center. The spinning cloud flattened into a disk of particles and gases circling the spot where the collapse took place. The strong force of gravity from the large clump of dust and gas eventually caused atoms inside it to combine and release energy as light and heat, allowing our sun to form. That was the beginning of our solar system.

Gravity formed the planets, too: when the sun formed, it consumed almost all of the particles in the center of the disk. However, there were some particles left over in the outer regions of the disk, circling and circling around the sun. As they moved, they crashed into each other and formed clumps with larger masses. With larger masses, gravity from these clumps pulled on nearby objects with even more force. Over time, those clumps grew large enough to become planets, moons, asteroids, comets and other objects in our solar system.

Since then, the solar system hasn't changed much. It's still a disk with objects circling the sun at the center. The sun's gravity plays a role in keeping those objects circling. In our solar system, each planet's orbit is pretty stable, never getting much closer to or farther from the sun. If the sun's gravity is so strong, how can that be?

The planets don't all collapse into the sun because they are moving too fast, and there is no force, like friction, to slow them down. The planets are moving sideways past the sun and have momentum in that direction. One way of thinking of momentum is to call it "mass in motion," and because planets have lots of mass and are moving very fast, they have lots of momentum. Although the planets' momentum is aimed in a straight line sideways past the sun, gravity from the sun pulls on the planets and causes them to move in a circle instead. The force of gravity from the sun can't stop the planets' sideways motion—it can only pull them toward the sun. If the sun disappeared and its gravitational pull suddenly stopped, all the planets would shoot off in the direction they were moving at that moment, leaving the solar system and moving far away into space. Luckily for us, gravity IS acting on the planets, and the gravitational pull of the sun combines with planets' momentum to keep them circling the sun.

Gravity isn't just an important force inside our solar system. Gravity is just as important in other star systems everywhere in the universe. Our solar system is part of a giant collection of more than 100 billion other stars called the Milky Way galaxy. The Milky Way galaxy is just one of many galaxies in the universe. Just as Earth orbits in a giant circle around the sun, our solar system orbits in an even larger circle around the center of the Milky Way galaxy. You might be thinking that there needs to be an object with a huge mass at the center of the galaxy to be able to exert enough gravitational pull to hold our entire solar system and 100 billion stars in orbit around it. You'd be right. In fact, scientists have evidence that there is a supermassive object known as a black hole at the center of the Milky Way galaxy that is 4 million times more massive than the sun.

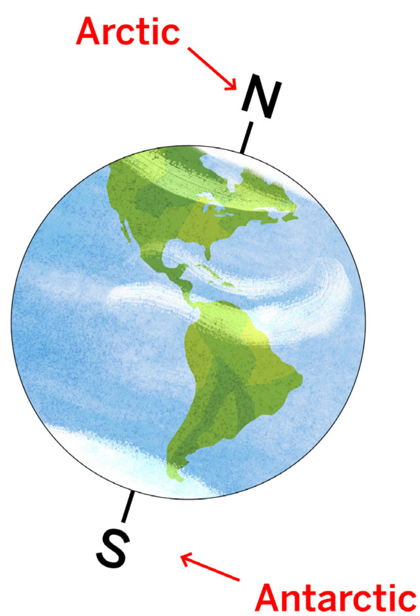


The planets have momentum in the sideways direction, but the sun pulls the planets toward its center with the force of gravity. This combination keeps the planets moving around the sun.

The Endless Summer of the Arctic Tern

Arctic terns fly about 2.4 million km (1.5 million mi) over the course of their lives.

The Arctic tern is a species of bird that lives in the Arctic—but only for part of the year. These terns fly very long distances to stay in parts of the planet that are experiencing summer. Every year, Arctic terns fly from the Arctic all the way to the Antarctic and back. Arctic terns live an average of 30 years and migrate about 2.4 million kilometers (1.5 million miles) during their lives! Why would these birds fly so far? It's all about sunlight.



The Arctic is the area around Earth's North Pole, while the Antarctic is the area around Earth's South Pole.

All Arctic terns are born in the far north, near the Arctic Circle. During the northern summer, the Arctic gets 24 hours of sunlight each day. At the same time, the Antarctic experiences a dark, dark winter—for months, the sun never rises at all. When the seasons change, conditions at the two poles switch: when the darkness of winter comes to the Arctic, the South Pole gets 24-hour sunlight. All that sunlight means plants and other producers are able to perform lots of photosynthesis and provide food for animals and other organisms. Warmer temperatures can also mean better conditions for reproducing and raising baby terns. Arctic terns fly back and forth between the Arctic and Antarctic as the seasons change so they have enough food to eat.

Earth has seasons because of the way the northern hemisphere (northern half) and the southern hemisphere (southern half) of Earth are oriented toward the sun. At certain times of year, as Earth moves in its orbit around the sun, one hemisphere of Earth is tilted toward the sun. While it's tilted toward the sun, that hemisphere receives more hours of sunlight each day than it does during other times of year, and the sunlight it receives is more intense than at other times of year. It is summer for that half of Earth. At the same time, the other hemisphere, or half, of Earth is tilted away from the sun and gets less intense sunlight for fewer hours each day—that's winter for that half of Earth. Earth's tilt does not change as Earth orbits the sun over the course of a year. As Earth travels, the hemisphere that starts out tilted toward the sun is eventually tilted away from it. Earth takes one year to orbit all the way around the sun, so each hemisphere of Earth experiences one summer and one winter each year.

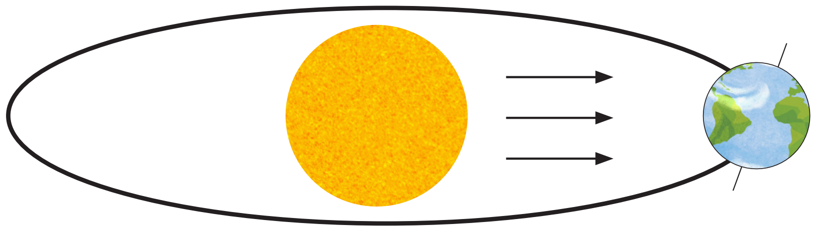
Just because it's summer in the Arctic when the Northern Hemisphere is tilted toward the sun, that doesn't mean it is very warm there. Summer temperatures in the Arctic average 0°C (32°F). These chilly summers happen because the Arctic never directly faces the sun, like locations closer to the equator do—the sun is never directly overhead at the Arctic. The same is true about the Antarctic. It is warmer at the South Pole when the Southern Hemisphere is tilted toward sun, but the average summer temperature is still below freezing!

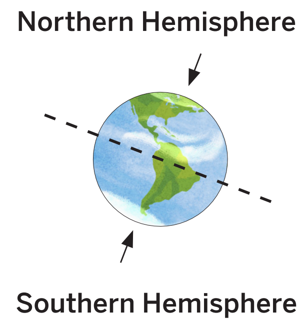
Arctic terns fly back and forth between the North Pole and the South Pole.

The Arctic tern's migration ensures the terns are always living where there's plenty of sunlight. When the Arctic is tilted toward the sun and experiences summer, the terns live there. When the seasons begin to change, the terns leave the Arctic and fly south. By the time the Antarctic is tilted all the way toward the sun, the terns have arrived at the Antarctic. They live there until the seasons change again, and fly north again. That way, they always live where it's summer.

Since Earth's seasons are all about how our planet is tilted, that means our seasons don't depend on how far Earth is from the sun. In fact, Earth's distance from the sun doesn't change very much as it orbits. One way we know this is true is because the whole planet doesn't experience the same season at the same time. For example, if summer were caused by Earth moving closer to the sun, you would expect the whole planet to have summer at the same time. But we know that only half of Earth experiences summer at the same time—it's when that hemisphere is tilted toward the sun.

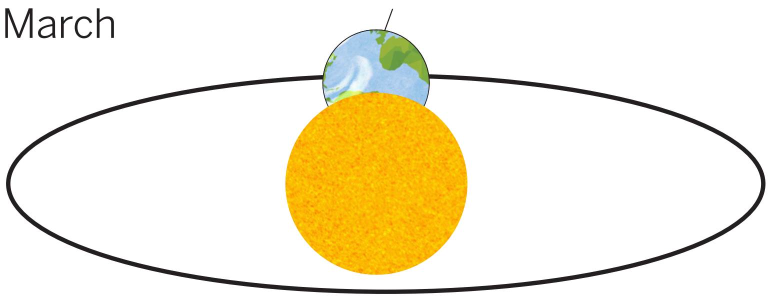
December





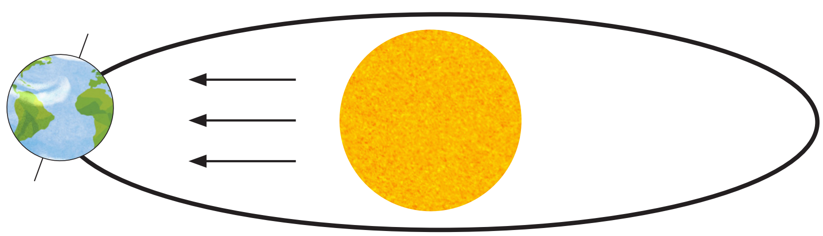
- Winter in the Northern Hemisphere, summer in the Southern Hemisphere
- Less intense sunlight and fewer hours of sunlight in the Northern Hemisphere

March



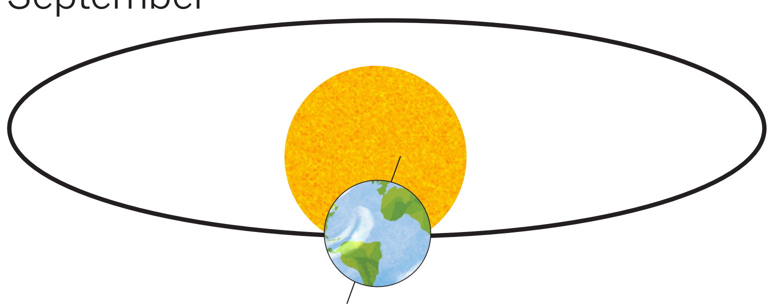
- Spring in the Northern Hemisphere, fall in the Southern Hemisphere
- The sun shines equally on both hemispheres

June



- Summer in the Northern Hemisphere, winter in the Southern Hemisphere
- More intense sunlight and more hours of sunlight in the Northern Hemisphere

September



- Fall in the Northern Hemisphere, spring in the Southern Hemisphere
- The sun shines equally on both hemispheres

An Ancient Machine for Predicting Eclipses

The Antikythera mechanism is a set of metal gears that predicted patterns in the position of the sun, the Moon, and the planets. The gears were found in the remains of an ancient sunken ship in the Mediterranean Sea.

Imagine diving 150 feet beneath the sea. You are looking for sponges, which is not very exciting, but it's your job. Now imagine coming across the wreck of an ancient ship! That's what happened to some divers off the island of Antikythera (an-tee-KITH-er-ah) in the Mediterranean Sea. The ship had been on the seafloor for almost 2000 years. Divers found coins, statues, musical instruments, and many other precious items in the shipwreck. The greatest treasure of all, however, was a collection of corroded metal gears. Nothing like them had ever been found before or has ever been found since. They seem to fit together in a complicated way. They are part of a machine that scientists call the Antikythera mechanism.

It took scientists many years to figure out what the mysterious machine was for. Eventually, scientists used x-rays to view the gears and other parts inside the machine. They were also able to read ancient Greek writing on some of the parts. Using this new information, scientists realized the Antikythera mechanism was built by ancient astronomers to predict patterns in the appearance of the sun, the planets that people were able to observe, and especially the Moon.

Ancient Greek astronomers had been observing the Moon and keeping track of its appearance for hundreds of years. Looking over all their observations, they noticed patterns. The astronomers assumed the same patterns that had been going on for hundreds of years would keep going into the future. They built the Antikythera mechanism to predict events in the future based on the patterns they had observed.

A user of the Antikythera mechanism could turn a dial on one side of the mechanism to choose a date and time, either in the past or in the future. The gears would spin into place, predicting the appearance and position of the Moon and other bodies at that time. The machine had pointers and other displays to show its predictions. For example, ancient astronomers knew there would be a full moon every 29 and a half days. There was a ball on the Antikythera mechanism that traced the phases of the moon. The ball was white on one side (representing the side of the moon illuminated by the sun) and black on the other (representing the dark side of the moon). As the user turned the date dial of the machine, the little moon ball would spin to show what phase the moon would be in on that date.

The Antikythera mechanism also traced patterns that took much longer to repeat.

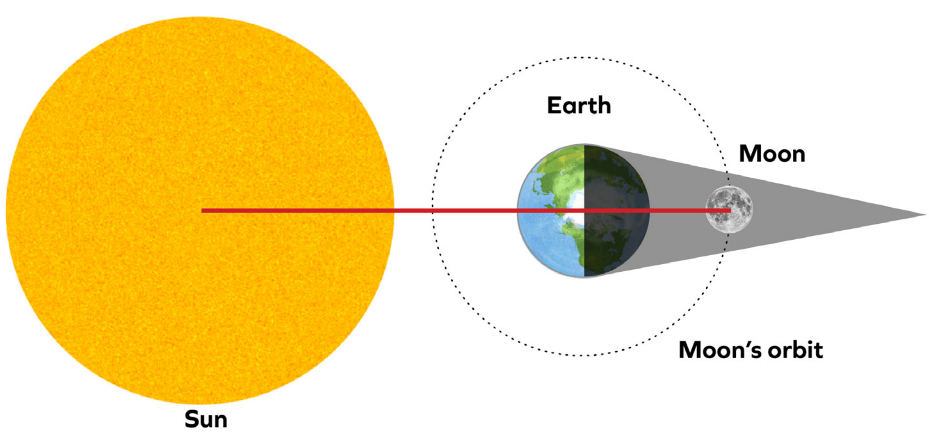
For instance, ancient astronomers knew that occasionally, on the night of a full moon, a lunar eclipse happens. During a lunar eclipse, the fully illuminated face of the full moon goes dark for a time. However, they noticed that this didn't happen every full moon—in fact, over a year would sometimes pass between their observations of lunar eclipses. Through careful record-keeping, the ancient astronomers realized that eclipses, although rare, happened in patterns. They kept track of the patterns and recorded that knowledge in the workings of the Antikythera mechanism. As a user turned the date dial of the Antikythera mechanism, the mechanism counted the days and displayed exactly when people in Greece could expect to observe a lunar eclipse.

The mechanism showed WHEN an eclipse would happen, but it didn't show WHY an eclipse would happen. The astronomers who made the Antikythera mechanism knew that the Moon seems to shine because it is illuminated by light from the sun. They also knew that an eclipse of the Moon happens when Earth blocks the sunlight and makes a shadow on the Moon. They did not know exactly why this happened at some times and not others.

Today astronomers can explain why lunar eclipses happen when they do. Lunar eclipses are caused by Earth blocking sunlight from reaching the Moon. For Earth to block the sunlight, it has to be between the sun and the Moon. Not only that, but the sun, Earth, and the Moon have to line up exactly, with Earth in the middle. When they line up in this way, Earth blocks the sunlight and the Moon goes dark. Eclipses only happen on the night of a full moon, because the full moon is the phase when the sun, Earth, and the Moon line up with Earth in the middle.

If this is true, why don't lunar eclipses happen every time the Moon is full? Why did the ancient astronomers have to wait so long between observations of eclipses? It's because the Moon's orbit around Earth is slightly tilted out of alignment. During most full moons, the sun, Earth, and the Moon are lined up, but they are not lined up EXACTLY. For the three bodies to line up exactly, the Moon has to be exactly in the right spot on its tilted orbit. That happens very infrequently. The makers of the Antikythera mechanism knew how unusual this was, but they didn't understand the reason—now you do!

Lunar Eclipse



During lunar eclipses, the sun, Earth, and the Moon are arranged in a straight line. Light from the sun is blocked by Earth and cannot reach the Moon.

Earth, Moon, and Sun:
An Astrophotographer's Challenge

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

AMP.NA18
ISBN 978-1-64089-870-7

Amplify. Published and Distributed by Amplify.
www.amplify.com