SEPUP

Issue-Oriented Science

ISSUES AND EARTH SCIENCE

Solar System and Beyond

THIRD EDITION

REDESIGNED FOR THE NGSS

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THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

LAB-AIDS®

This book is part of SEPUP's *Issues and Science* course sequence. For more information about this sequence, see the SEPUP and Lab-Aids websites.

ISSUES AND EARTH SCIENCE

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A Letter to *Issues and Earth Science* Students

As you examine the activities in this book, you may wonder, "Why does this book look so different from other science books I've seen?" The reason is simple: it is a different kind of science program, and only some of what you will learn can be seen by leafing through this book!

Issues and Earth Science uses several kinds of activities to teach science. As you conduct these activities, you will engage in the same practices used by scientists to understand the natural world and by engineers to solve problems. For example, you will plan and carry out an experiment to investigate how water and sand heat up differently. You will analyze and interpret data on ocean temperatures and worldwide winds. And you will examine evidence for links between climate change, global warming, and human activity. A combination of laboratories, investigations, readings, models, scientific debates, role plays, and projects will help you develop your understanding of science and the relevance of earth science to your interests.

You will find that important scientific ideas come up again and again in different activities throughout the program. You will be expected to do more than just memorize these concepts: you will be asked to develop explanations and apply them to solve problems. In particular, you will improve your decision-making skills by using evidence to weigh outcomes and to decide what you think should be done about the scientific issues facing our society.

How do we know that this is a good way for you to learn? In general, research on science education supports it. In particular, many of the activities in this book were tested by hundreds of students and their teachers, and then modified on the basis of their feedback. New activities are based on what we learned in classrooms using the materials and on new research on science learning. In a sense, this entire book is the result of an investigation: we had people test our ideas, we interpreted the results, and we then revised our ideas! We believe the result will show you that learning more about science is important, enjoyable, and relevant to your life.

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The classroom is SEPUP's laboratory for development. We are extremely appreciative of the following center directors and teachers who taught the program during the 2003–04 and 2004–05 school years. These teachers and their students contributed significantly to improving the first edition of the course. Since then, *Issues and Earth Science* has been used in thousands of classrooms across the United States. This third edition is based on what we have learned from teachers and students in those classrooms. It also includes new data and information, so the issues included in the course remain fresh and up-to-date.

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Solar System and Beyond

Solar System and Beyond

DEVI WAS UP *early in the morning, even before the Sun, and looked outside through the kitchen window to see what appeared to be a tiny sliver of the Moon. Devi's mom noticed Devi looking perplexed and asked, "What are you thinking about?"*

Devi replied, "I thought the Moon was only out during the night."

Devi's mother replied, "The Moon is out at different times of the day depending on what phase it's in. The Moon's phases follow a consistent pattern that was first written down over 30,000 years ago."

"Wow!" exclaimed Devi, "How does the Moon work? Why does it change its shape?"

"Well, the Moon doesn't actually change its shape. It just looks different at different times. I think the Moon's orbit around Earth has something to do with what causes the changes to the Moon's appearance," explained Devi's unsure mother.

"Orbit… kind of like how Jupiter and other planets follow a curved path around the Sun?" Devi inquired.

Devi's mom responded, "Exactly! All the planets in our Solar System orbit the Sun, even Earth. It may not seem like we're moving, but we are."

"Whoa… that's crazy. I'd never thought about it like that! I wonder," said Devi, "if we could send a spaceship to take a video of Earth going around the Sun."

"Well, we could, but since space missions are so expensive, scientists usually investigate questions that are harder to answer. For instance, How did the Solar System form? Is there life on other planets or moons? And, where will humans go next?" Devi's mom said.

• • •

Why do we observe changes to the Moon's appearance? What causes the Earth's seasons? How far away and large are other objects in our Solar System? What is gravity, and why is it so important?

In this unit, you will take observations from your everyday life and build scientific models to try to understand how these phenomena work. You will collect and analyze data to gain a better understanding of the size and scale of our Solar System and of our Galaxy. You will use your understanding of what can be learned through space exploration to determine the trade-offs of different proposed space missions.

1 *Exploring Space*

TALKING IT OVER

THROUGHOUT HISTORY, SPACE has fascinated people. For a long time, people could only use their eyes to make observations of the night sky. In the early 1600s, a scientist named Galileo used a telescope to get a better look into space. Although Galileo did not invent the telescope, he was the first person to use the instrument to observe the night sky. Looking at the Moon through his telescope, Galileo observed that the surface of the Moon was rough and uneven. It wasn't smooth like people had thought. Since then, scientists and engineers have developed many new technologies for exploring space. **Spacecraft** (including rockets, satellites, probes, space stations, and space shuttles) carry tools and equipment to gather data about space and space objects.

In the United States, the National Aeronautics and Space Administration (NASA) is the government agency that conducts space exploration. Missions with NASA spacecraft have increased our understanding of our planet, other objects in our Solar System, our Sun, and other stars. But space missions are very expensive. And while many have been successful, some have not. Some missions have ended in disaster. There are many challenges involved in space exploration. So scientists and engineers must carefully consider which missions to fund.

The 2017 NASA Astronaut Class

GUIDING QUESTION

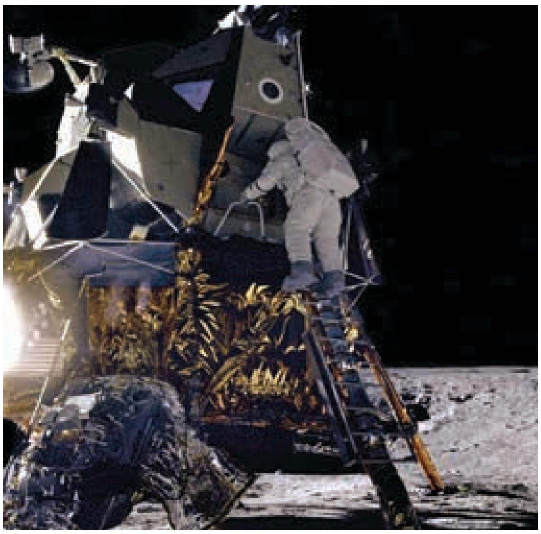
What have we learned from missions to space?

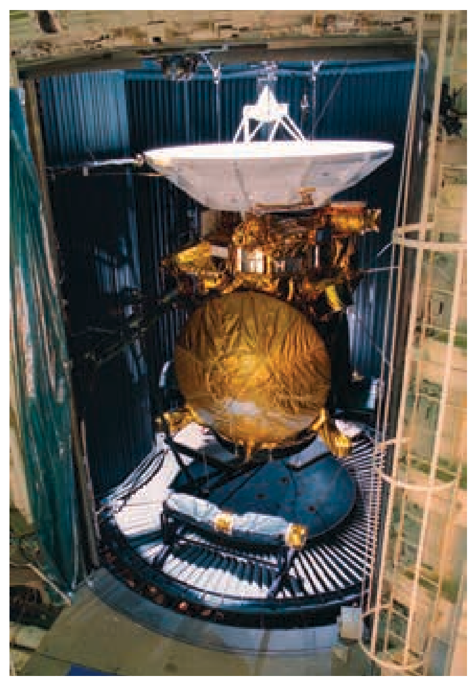
MATERIALS

For each student

1 Student Sheet 1.1, "Anticipation Guide: Space Exploration"

1 Student Sheet 1.2, "Four Space Missions"





An astronaut (top left) climbing down a lunar module on the surface of the Moon.

A photo of space taken from the Hubble Space Telescope (top right).

A photograph of the surface of Mars (above) taken by an unmanned spacecraft.

The Cassini spacecraft (right) undergoing testing in the space simulator before going into space to study Saturn and its moons.

PROCEDURE

Use Student Sheet 1.1, "Anticipation Guide: Space Exploration," to prepare for the following activity.

1. Each person in your group of four will read about one of the four missions to space. As you read, record information on Student Sheet 1.2, "Four Space Missions," about
   - what was learned from that space mission.
   - the challenges faced during that space mission.
2. Share what you learned about your space mission with your group. Tell your group members about the mission, what was learned, and what challenges were faced.
3. Make sure each person in your group has a chance to share. As you listen to others share, write down information about the other three space missions on Student Sheet 1.2.
4. Discuss the similarities and differences between the four missions your group read about.

MISSIONS TO SPACE

Apollo Program

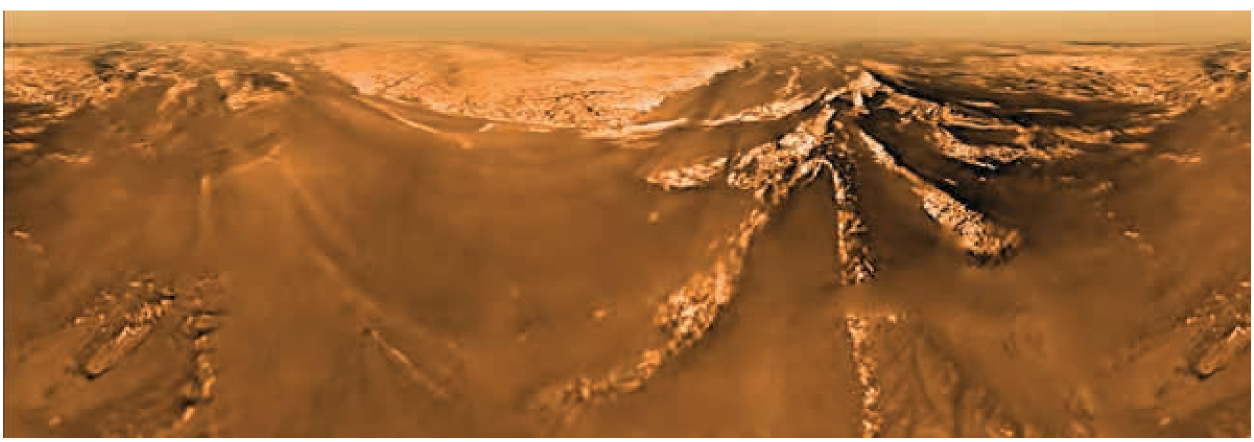
The Apollo program began in 1961 and ended in 1972. The Apollo program's goal was to send humans to the surface of the Moon to conduct scientific investigations. The program succeeded in landing six different Apollo missions on the Moon. A total of 12 astronauts walked on the Moon. In each mission to the Moon, astronauts collected data about its surface using a variety of equipment. Scientists learned what types of rocks exist on the surface of the Moon. They also learned that geological processes have occurred on the surface, including volcanic eruptions and impacts from space objects. By testing rock samples returned from the missions, scientists learned that there has never been life on the Moon.

An Apollo astronaut collects data on the surface of the Moon.

There were many challenges and risks involved in sending humans to the Moon. One challenge was providing food and drinking water for the 8–12 days of the missions. To address this challenge, NASA scientists built water filtration systems that provided astronauts with fresh drinking water. NASA scientists also developed a process for removing all the water from food. This process allowed the food to keep its nutrients and taste but not spoil. Astronauts could rehydrate the food with water while in space. On the Apollo missions, the astronauts had access to hot water to use when rehydrating their food; on previous missions to space, only cold water was available.

Cassini Mission

The Cassini mission involved an unmanned spacecraft and probe sent to explore Saturn. The mission's goal was to gather data about the planet and its moons using a variety of scientific instruments. The spacecraft launched on October 15, 1997, and entered Saturn's orbit 7 years later. From the data collected, scientists discovered seven of Saturn's moons and learned that Saturn's rings are constantly changing.



This photograph was taken as the Huygens probe fell to the surface of Titan.

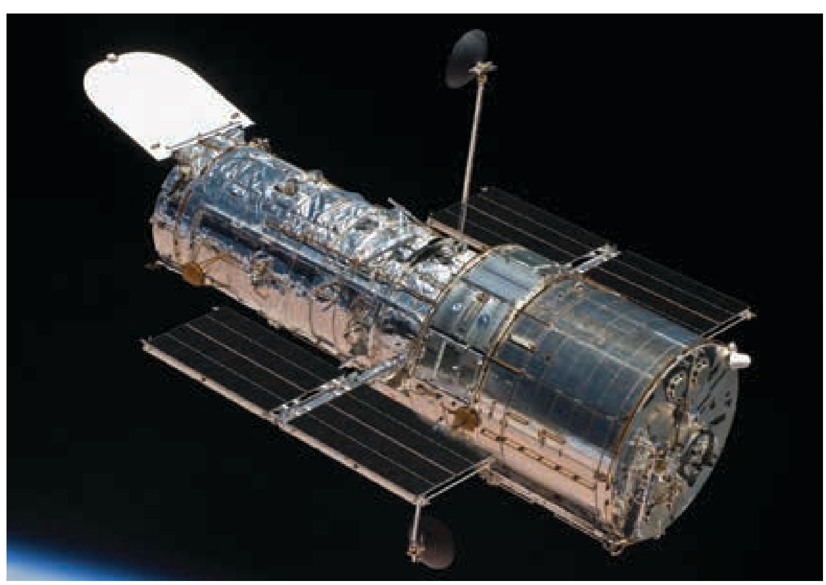
One challenge scientists faced during the mission had to do with the Huygens [*hoy*-gens] probe. This probe was to be dropped on the surface of Titan, one of Saturn's moons, to gather data. As Cassini traveled to Saturn, scientists from the European Space Agency working on the mission with NASA discovered a problem. This problem needed to be solved before Cassini reached its destination. They figured out that the Huygens probe would not be able to communicate with the Cassini spacecraft from the surface of Titan if Cassini followed the planned route. The European scientists and NASA scientists worked together to change the course of Cassini to solve this problem. When the Huygens probe landed on Titan, it became the first spacecraft to land on a moon so far out in our Solar System. It was also the most distant landing from Earth. Both the Huygens probe and Cassini took pictures of Titan's surface. From these pictures, scientists learned that liquid flowing on the surface of Titan has formed rivers, lakes, and seas. This is similar to how liquid water has shaped the surface of Earth.

After 20 years in space, the Cassini mission ended in September 2017. The "grand finale" of the mission was sending the Cassini spacecraft into Saturn's atmosphere, where it burned up and was destroyed.

Hubble Space Telescope

Scientists have used telescopes to observe the sky at night for hundreds of years. When looking out at space from Earth's surface, small particles, like the gases in Earth's atmosphere, can make it impossible to see some space objects clearly. To address this problem, the Hubble Space Telescope was launched in 1990. The goal was to use the telescope to collect data about space from beyond Earth's atmosphere. The Hubble Space Telescope orbits Earth 569 kilometers (km; 353 miles) above the surface. The telescope's placement above Earth's atmosphere allows scientists to gather more data about space objects than they can from Earth's surface. Scientists have determined the age of our Galaxy by gathering data with the Hubble Space Telescope about key moments in the the formation of stars and planets. They have also discovered new planets, solar systems, and galaxies beyond our own. Scientists from all over the world can apply to use the telescope to make their own observations of space objects. Since it launched, there have been over 15,000 scientific articles published using data from the Hubble Space Telescope!

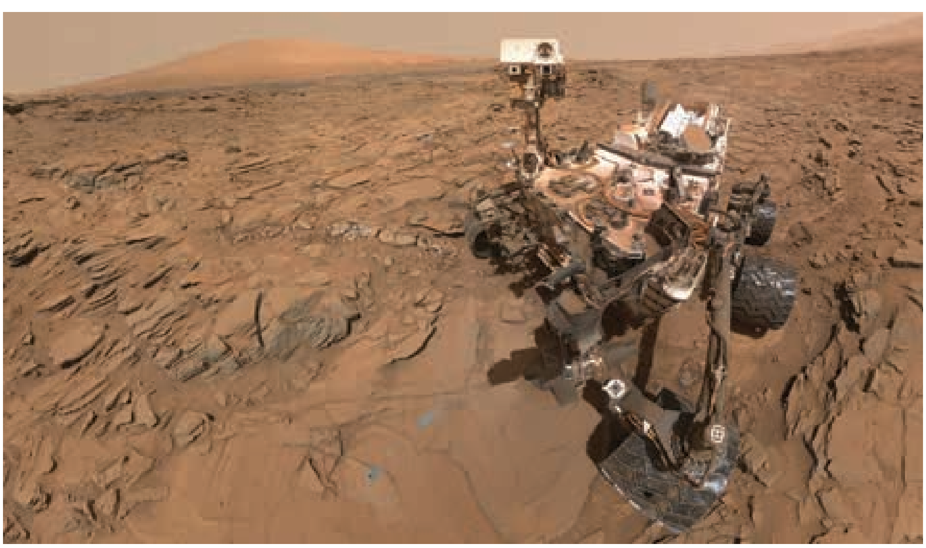
The Hubble Space Telescope collects data in space.



One challenge in using a telescope in space is keeping it working. On Earth's surface, people can repair or update equipment on a telescope as needed. But in space, it becomes difficult to maintain a telescope and update its technology. Because of this, the Hubble Space Telescope was designed to be repaired and serviced in space by astronauts. There have been six servicing missions where astronauts have repaired, updated, and added new equipment to the Hubble Space Telescope. The future for the Hubble Space Telescope is unclear, as there is no space shuttle mission planned to service or retrieve it, so it is likely that the instruments will fail or it will be destroyed as gravity pulls it down into Earth's atmosphere.

Mars Science Laboratory

The Mars Science Laboratory mission was launched in 2011. The goal of this active mission is to determine if life ever existed on Mars. As part of the Mars Science Laboratory mission, NASA scientists developed an unmanned spacecraft (the Curiosity Rover) to investigate the surface of Mars. The Curiosity Rover landed on Mars with a variety of tools and scientific instruments. It gathered and analyzed rock, soil, and air samples. From the observations and data gathered, scientists have found evidence that Mars had a very different environment in the past. Scientists learned that liquid water once flowed on Mars's surface and collected in lakes. Liquid water is one of the necessary conditions to support life, and Curiosity continues to gather data to find evidence of life on Mars.



The Curiosity Rover collects data on the surface of Mars.

One challenge the mission faced was safely landing Curiosity on Mars's surface. Curiosity is much larger and heavier than any other rover that NASA had sent to Mars. In past rover missions, airbag systems were used for landing. These systems would cushion the rover and protect the sensitive instruments inside from the impact of landing. But Curiosity is so heavy that engineers couldn't find any fabric on Earth that would be strong enough to make its airbags. To overcome this challenge, NASA scientists and engineers developed a new way to land Curiosity on the surface. They designed and built a new sky crane system that on August 6, 2012, gently lowered the rover down to the surface of Mars.

A computer generated illustration of the sky crane that landed the Curiosity Rover on the surface of Mars.

ANALYSIS

1. Return to Student Sheet 1.1, and complete the "After" column by marking whether you agree (+) or disagree (–) with each statement. Under each statement, explain how the activity gave evidence to support or change your ideas.

   Evidence is information that supports or refutes a claim.

2. Governments sometimes fund space missions instead of using that money for other scientific research on Earth. Would you fund a future space mission? Explain why, and provide an example of a trade-off between funding a space mission and funding other types of scientific research.

   A **trade-off** is a desirable outcome given up to gain another desirable outcome.

3. **Reflection**: If you had to choose a place in space to explore, where would it be? Explain why you chose this place and what new things you would want to learn.

EXTENSION

Visit the *SEPUP Third Edition Solar System and Beyond* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition* to learn about other missions to space. As you learn about a space mission, answer the following questions:

- What type of spacecraft was used?
- What were the goals of the mission?
- What was learned?
- What were the challenges?

2 The Predictable Moon

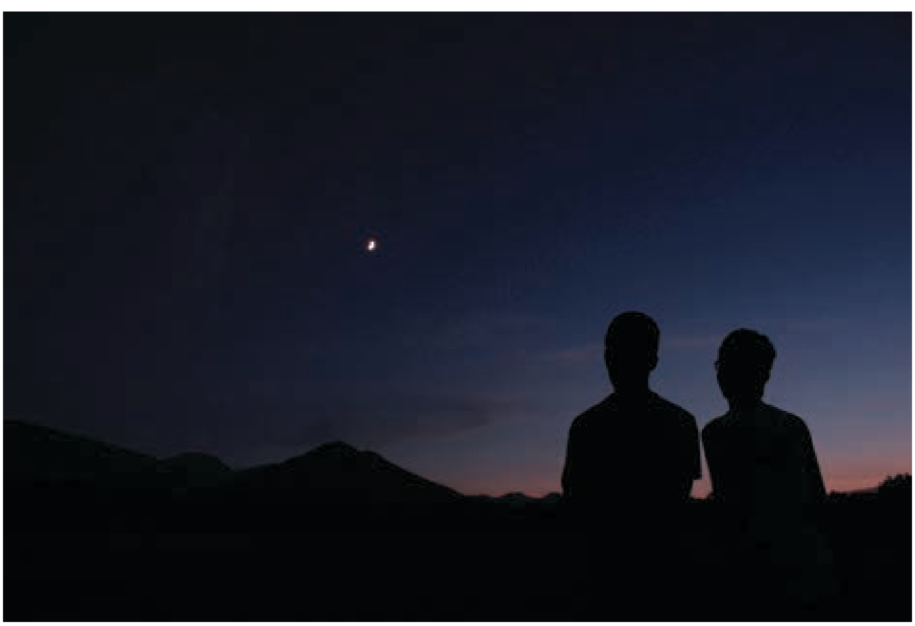
INVESTIGATION

Even without advanced technologies, you can learn about space from making observations with your eyes about objects in the sky. An **observation** is any description or measurement gathered by a person's senses or with instruments. The Moon is one of the easiest objects in the sky to observe. You probably have noticed that the Moon looks different on different days. The different shapes of the Moon visible from Earth are called **moon phases**.

The changing phases of the Moon have fascinated people for thousands of years. Long before clocks or calendars, many cultures used the Moon's changing phases for measuring time. In this activity, you will investigate the Moon's predictable phases.

GUIDING QUESTION

How can we predict changes in the Moon's appearance?



Students observing the Moon from Earth's surface.

MATERIALS

For each pair of students

1 set of 8 Moon Phase Cards

For each student

1 Student Sheet 2.1, "Moon Observations"

PROCEDURE

Part A: Moon Phase Cards

1. With your partner, look at all of your Moon Phase Cards and discuss if you have ever seen the Moon appear as it does on each card.
2. Place your cards in an order, from left to right, that you think shows how the Moon's appearance changes over time. Record your reasoning in your science notebook.
3. Compare the order of your cards with the order created by the other pair in your group. Discuss your reasoning for the order you chose, and identify any similarities and differences between the two orders.
4. A **cycle** is a sequence of events that repeats. As a group, combine and order the two sets of Moon Phase Cards, from left to right, to show how the changes in the Moon's appearance are part of a cycle.
5. Discuss Analysis item 1 with your group. Record your answer in your science notebook.

Part B: Moon Observations

6. Student Sheet 2.1, "Moon Observations," has a calendar where observations of the Moon's phases have been filled in on certain dates. Using the observations on the calendar, discuss how many days a complete cycle of the Moon's phases takes.
7. In the circles on Student Sheet 2.1 for May 11, 22, and 28, draw what you think the Moon will look like on those days.
8. Predict the date for the next full moon for the June calendar on Student Sheet 2.1. Draw a full moon on the date you predicted.
9. On Student Sheet 2.1, write the word "new moon" on the days you predict the new moon will occur.

ANALYSIS

1. In Step 4, if you had moved your first card to the end of your order, would the order still be correct? Explain your answer using the word pattern in your explanation. A **pattern** is something that happens in a repeated and predictable way.

2. Explain how you made your predictions for Steps 7 through 9.

3. Predict the date of the next first quarter moon for the June calendar on Student Sheet 2.1. Explain how you made your prediction.

4. **Reflection**: Why do you think the Moon's appearance changes?

3 *Explaining the Moon's Phases*

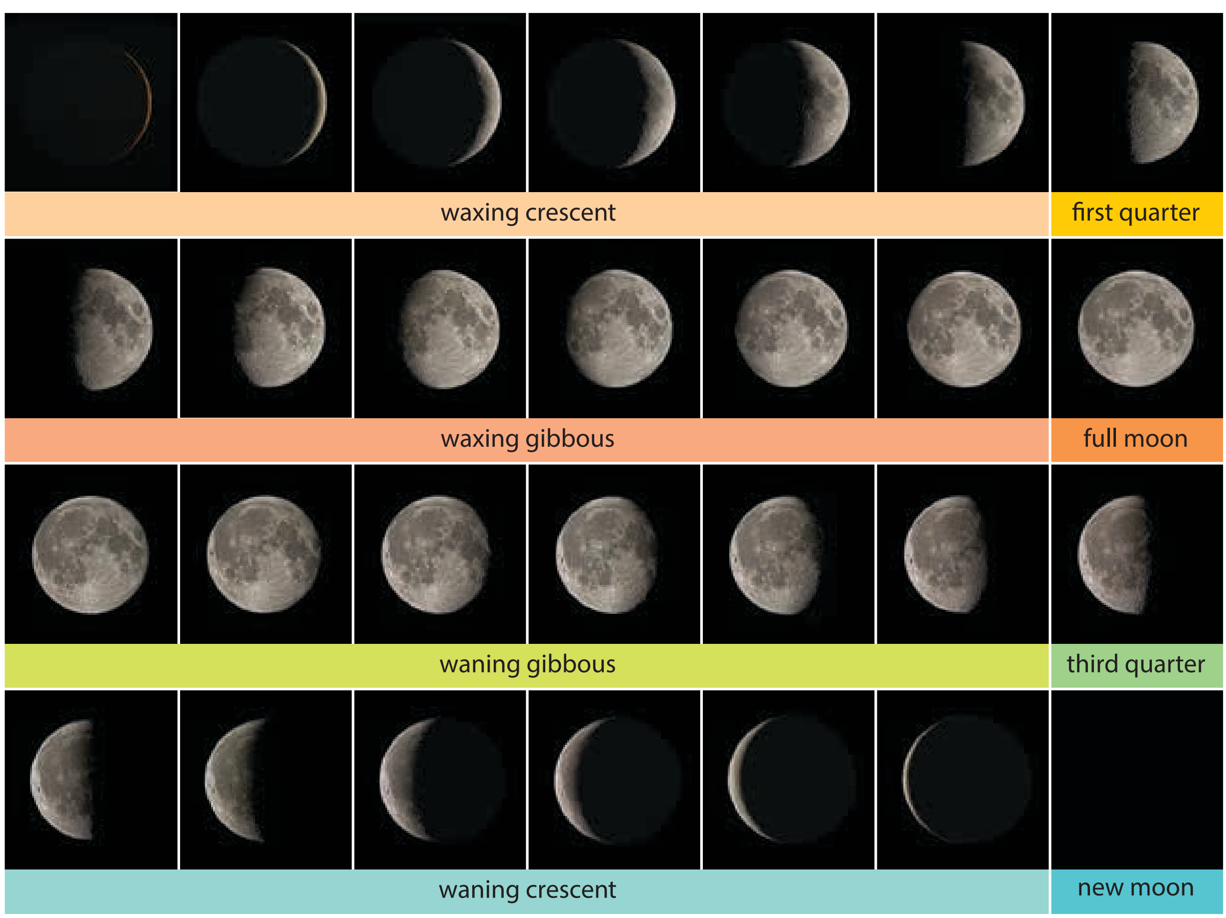
MODELING

IN THE LAST activity, you investigated the cycle of the Moon's phases. To help you understand why people on Earth observe this cycle, you will use a model of the Sun, Earth, and Moon. A **model** is any representation of a system used to help one understand and communicate how it works. Scientists build and use models to try to explain what they observe in nature.

GUIDING QUESTION

What causes the cycle of the Moon's phases that we observe from Earth?

Moon Phases



MATERIALS

For the class

1 light source

For each pair of students

1 Moon model: a white foam ball attached to a stick

For each student

1 Student Sheet 3.1, "Observations of Moon Model"

PROCEDURE

1. Watch closely as your teacher demonstrates how you and your partner will model the Moon's orbit around Earth.

To create your model, you will use a light to represent the Sun (because the Sun produces light), a ball to represent the Moon, and your head to represent Earth. You will observe the appearance of the Moon in its orbit around the Earth. The curved path that a space object takes around another star, planet, or moon is called its **orbit**.

2. Position yourself as instructed by your teacher, and model one complete orbit of the Moon around Earth. Observe the Moon's appearance throughout the modeled orbit. Your partner should then repeat this step.
3. Repeat Step 2, except make sure to stop at each of the positions shown on Student Sheet 3.1, "Observations of Moon Model." For each position, observe the Moon model, and draw your observations of the Moon model on your Student Sheet. Your partner should then repeat this step.
4. On Student Sheet 3.1, complete the final diagram by drawing the Moon so that it shows where you think the Sun, Moon, and Earth are located during a first quarter moon. Explain why you would see a first quarter moon.

   Hint: If you are having trouble figuring this out, have your partner use the model to find the first quarter moon phase, and then draw where the Sun, Earth, and Moon are positioned.

ANALYSIS

1. What fraction of the Moon model was always lit up by the light in your model?
2. What fraction of the Moon is always lit up by the Sun?
3. Why can't you see a new moon?
4. Although we call it *moonlight*, where does the light that we see coming from the Moon actually come from?
5. Your friend claims that the Moon's repeated orbit around Earth causes the cycle of the Moon's phases.
   a. Do you agree or disagree with your friend? Use your observations from this activity to support your answer.
   b. Does your friend's claim make sense with the predictable cycle of the Moon's phases that you observed in the previous activity? Explain.
6. In this activity, you modeled the Sun–Earth–Moon system. If you removed one object from this system model, would the model still explain the changes to the Moon's appearance? Explain your ideas.

A **system** is a group of interacting objects or processes. Every system includes

- components: the substances, materials, and processes that make up the system.
- interactions: the relationships between the substances, materials, and processes in the system.
- boundaries: the extent of the system, separating those component and processes that are part of the system from those that are not.

4 Moon Phase Simulation

COMPUTER SIMULATION

IN THE LAST activity, you used a model to see how different amounts of the Moon appear to be lit up by the Sun as the Moon orbits Earth. You also noticed that the Sun always lights up the half of the Moon facing toward the Sun, while the half of the Moon facing away from the Sun is in darkness. Depending on where the Moon is in its orbit, we can see some fraction of the half of the Moon that is lit up by the Sun.

In this activity, you will use a computer simulation that will allow you to observe the Moon's orbit around Earth from a different point of view. Scientists often use simulations and other models to study systems that are difficult to observe directly. In this case, your point of view will be looking down on the Earth–Moon system from out in space.

GUIDING QUESTION

How does the Moon's orbit around Earth cause the Moon's phases to repeat around every 29 days?

MATERIALS

For each pair of students

1 computer with Internet access

PROCEDURE

Part A: Exploring the Simulation

1. Open the Moon Phase Simulation on your computer.
2. Identify the sunlight, Earth, and Moon.

   Note: The view in the model is from above Earth's North Pole.
3. Discuss with your partner what the large circle around Earth represents.
4. Press "Play," and observe what the Moon does and what Earth does.
5. Discuss your observations with your partner. Make sure to discuss what Earth's rotation is modeling.

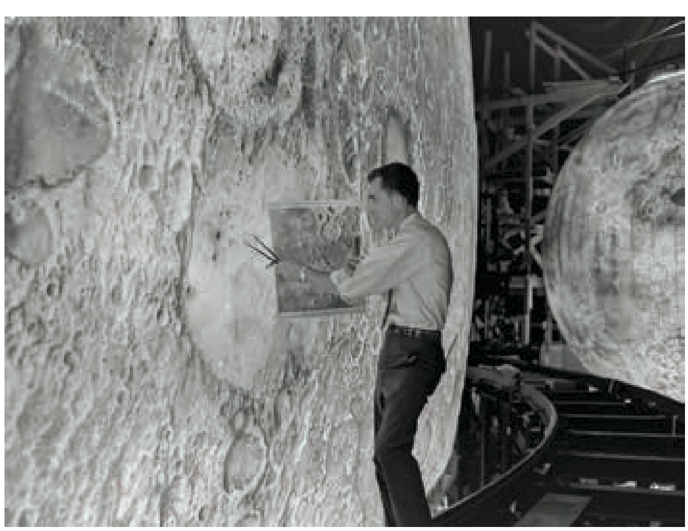
Part B: Observing the Phases

6. After watching the Moon orbit Earth one time, press "Pause."
7. Select "new moon" in the drop-down menu under Select Moon Phase.
8. Look carefully at where the Moon is in relation to Earth and sunlight, and what its phase looks like. Make a labeled sketch in your science notebook of your observations. Title your sketch with the name of the moon phase.
9. Press "Play," and watch the simulation until the Moon is in the first quarter phase, and then press "Pause."
10. In your science notebook, make a sketch similar to the one you made in Step 8.
11. With your partner, make predictions of where you think the Moon will be in its orbit during the: full moon, third quarter moon, and waning crescent moon. Sketch your predictions in your notebook.
12. Select the phases described in Step 11 in the drop-down menu under Select Moon Phase, and observe whether your predictions in Step 11 were correct. Correct your sketches as needed.

13. Press "Play" and then press "Fast Forward" to make the simulation go more quickly. Observe the pattern between how the Moon's position changes and how the Moon's phase changes.

ANALYSIS

1. In the simulation, what do the dark and light halves of the Moon and Earth represent?
2. Why are the light halves of the Moon and Earth always shown facing the incoming sunlight?
3. A simulation can be thought of as another type of model. Compare this computer simulation to the physical model your teacher showed you in "Explaining the Moon's Phases" activity.
   a. What are the advantages and disadvantages of using the ball and light to represent the Moon and the Sun?
   b. What are the advantages and disadvantages of the computer simulation?
   c. Why do we use models to understand how the Moon orbits Earth instead of traveling into space to observe the phenomenon?
4. Draw a model, and use it to explain the reason we see the cycle of the Moon's phases.
5. NASA scientists often use simulations to prepare for space missions. During the Apollo program, NASA scientists and engineers built a simulator called Project LOLA. Using the simulator, astronauts could practice flying over the surface of the Moon to find their landing spot. Why do you think NASA engineers and scientists developed Project LOLA?



A NASA employee working on the Moon model for the Project LOLA simulator.

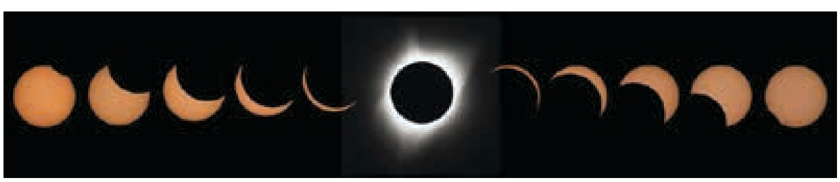
5 The Moon's Orbit

MODELING

Most diagrams and models of the Moon's orbit around Earth are two-dimensional, or flat. In these diagrams, it looks like we should see a solar eclipse and a lunar eclipse every month. A **solar eclipse** is when the Moon passes directly between Earth and the Sun, causing some places on Earth to experience darkness during daytime. A **lunar eclipse** is when the Moon passes into Earth's shadow, and people on Earth see the Moon darken even though it is a full moon. In reality, there are an average of four eclipses every year. So why are two-dimensional images and models of the Sun-Earth-Moon system inaccurate? In this activity, you will use a three-dimensional model to investigate this question.

GUIDING QUESTION

Why don't we see lunar and solar eclipses more often?



A time-lapse photograph of the solar eclipse that occurred on August 21, 2017.

A time-lapse photograph of the lunar eclipse that occurred on April 14, 2015.

MATERIALS

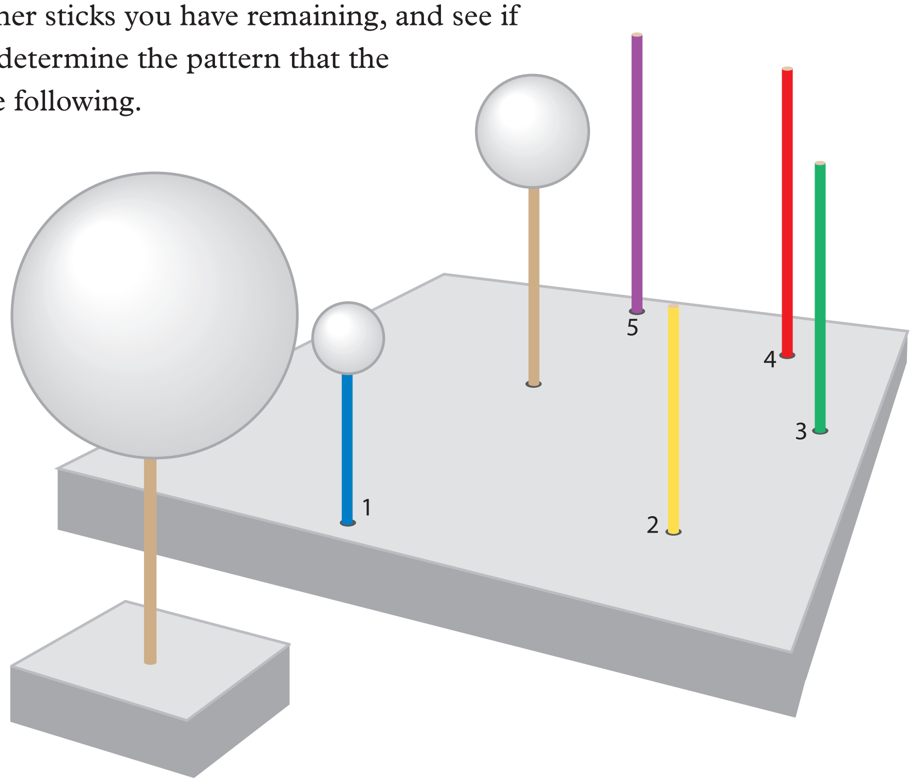
For each group of four students

- 1 Earth model: a medium white foam ball attached to a stick
- 1 Sun model: a large white foam ball attached to a stick
- 1 Moon model: a small white foam ball with a hole in it
- 1 blue stick
- 2 yellow sticks
- 2 green sticks
- 2 red sticks
- 1 purple stick
- 1 foam board with labeled holes
- 1 piece of foam
- 1 blank sheet of paper
- 1 marker

PROCEDURE

Part A: Completing One Orbit

1. Set up Earth and the Sun as instructed by your teacher.
2. Place the blue stick in position #1, and add the Moon to the top of the stick. Discuss with your group which moon phase you would see from Earth. Record your ideas in your science notebook.
3. Place a yellow stick in position #2, a green stick in position #3, a red stick in position #4, and a purple stick in position #5. Look at the other sticks you have remaining, and see if you can determine the pattern that the sticks are following.



4. Decide with your group which stick should go in which position. Place the sticks in those positions.
5. Move the Moon ball from stick to stick, making sure to observe the height of the Moon compared with Earth and the Sun. Discuss with your group what the Moon's phase is at each position. Record your observations in your science notebook.
6. Move the Moon ball to the stick in the position it needs to be in for there to be a full moon, and discuss whether there would be a lunar eclipse.

   Note: Lunar eclipses can only happen during a full moon.

Part B: The Orbital Plane

7. Remove Earth, the Moon, and the Sun from your model, but leave the sticks in their positions.
8. Have one member of your group hold a piece of paper so that it touches the top of each of the sticks. This piece of paper is a model of the Moon's **orbital plane**, the flat two-dimensional plane where the Moon is at any point in its orbit. Notice how the Moon's orbital plane is tilted relative to the line between Earth and the Sun.
9. Have a different member of your group use a marker to put a dot where each of the sticks touches the modeled orbital plane.
10. Add a dot in the center of your drawing and label it "Earth."
11. At one end of your paper, add arrows that represent light coming from the Sun toward Earth and the Moon.
12. Looking at where you added the sunlight and where Earth is located, discuss where the different phases of the Moon would occur.
13. As a group, label each dot with which phase of the Moon it represents.
14. Keep your model set up as you work on the Analysis.

ANALYSIS

1. The Moon takes about 29 days to orbit Earth. In this activity, there were eight positions the Moon could be in.

   a. How many days would it take for the Moon to get from position #2 to position #4 in its orbit?

   b. What phases would the Moon go through as it traveled from position #2 to position #4?

2. In Step 9, you created a two-dimensional drawing of the Moon's orbit. What information about the Moon's orbit is missing from the two-dimensional drawing?

3. There are two points during the Moon's orbit around Earth when the Moon, Earth, and Sun are all in the same plane. In your model, this is represented when the Moon is on the green stick such that the Moon, Earth, and Sun are all at the same height.

   a. If the Moon is on the green stick in position #6, in what phase is the Moon? Draw what that phase looks like, and explain why it looks that way.

   b. If the Moon is on the green stick in position #1, in what phase is the Moon? Explain what people on Earth would observe.

   c. And when the green stick is in position #1, what color stick should be in position #5? Explain.

4. **Reflection**: How have your ideas about the reason for the phases of the Moon changed since you began this unit?

EXTENSION

Visit the *SEPUP Third Edition Solar System and Beyond* page of the SEPUP website at *www.sepuplhs.org/middle/third-edition* for more information about solar and lunar eclipses.

6 *Changing Sunlight*

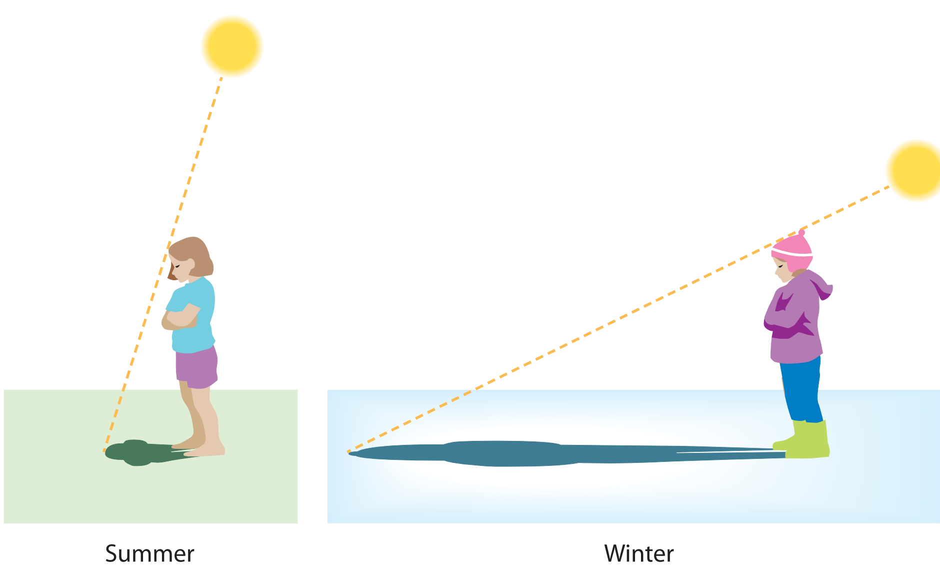
INVESTIGATION

THE SUN, UNLIKE the Moon, doesn't change phases. The Sun always appears to be a full circle because it produces its own light. You have probably observed that the Sun seems to move through the sky over the course of a day. But have you noticed that the Sun's path through the sky changes from day to day? The amount of time the Sun is up also changes from day to day.

In this activity, you will investigate changes in how long the Sun is up and the Sun's highest position in the sky over the course of a year.

GUIDING QUESTION

What do you observe about the length of daylight and the position of the Sun in the sky over the course of a year?



A student observes the length of their shadow at noon in summer and in winter.

MATERIALS

For each pair of students

1 protractor
1 pair of scissors
2 black pens or pencils
2 colored pens or pencils (both the same color)
transparent tape
1 Student Sheet 6.2a, "Graph of Daylight Length and Sun Angle vs. Month: Year 1"
1 Student Sheet 6.2b, "Graph of Daylight Length and Sun Angle vs. Month: Year 2"

For each student

1 Student Sheet 6.1, "Anticipation Guide: Sunlight and Seasons"

PROCEDURE

Use Student Sheet 6.1, "Anticipation Guide: Sunlight and Seasons," to prepare for the activities that follow.

1. Review the data in the following tables: "Daylight Hours and Sun Angle: Year 1" and "Daylight Hours and Sun Angle: Year 2." These data are typical of would be collected over the course of a year in the United States.

   Note: The United States is in Earth's Northern Hemisphere.

2. Describe in your science notebook the pattern you observe for the:
   a. time of sunrise
   b. time of sunset
   c. length of daylight
   d. highest angle of the Sun in the sky

3. Compare the patterns you described in Step 2 to see if any of the patterns are similar to one another. Record your observations in your science notebook.

4. Working as partners, one person should use Student Sheet 6.2a, "Graph of Daylight Length and Sun Angle vs. Month: Year 1," to prepare a scatterplot graph of daylight length and the Sun's highest angle vs. month based on the data in the table "Daylight Hours and Sun Angle: Year 1." The other partner should use Student Sheet 6.2b, "Graph of Daylight Length and Sun Angle vs. Month: Year 2," to prepare a similar scatterplot graph based on the data in the table "Daylight Hours and Sun Angle: Year 2." Agree on which color to use to plot daylight length and which color to use to plot the Sun's highest angle.

Daylight Hours and Sun Angle: Year 1

MONTH*	TIME OF SUNRISE (A.M.)	TIME OF SUNSET (P.M.)	DAYLIGHT (HOURS)	SUN'S HIGHEST ANGLE (DEGREES)
January	8:12	5:52	9.7	28.4
February	7:37	6:31	10.9	37.8
March	6:51	7:04	12.2	48.6
April	6:00	7:38	13.6	60.2
May	5:24	8:10	14.8	68.4
June	5:15	8:29	15.2	71.6
July	5:34	8:19	14.8	68.4
August	6:05	7:41	13.6	60.0
September	6:37	6:48	12.2	48.6
October	7:10	5:59	10.8	37.2
November	7:47	5:24	9.6	28.1
December	8:14	5:22	9.1	24.7

**Data were collected on the 21st day of each month.*

Daylight Hours and Sun Angle: Year 2

MONTH*	TIME OF SUNRISE (A.M.)	TIME OF SUNSET (P.M.)	DAYLIGHT (HOURS)	SUN'S HIGHEST ANGLE (DEGREES)
January	8:12	5:51	9.7	28.4
February	7:37	6:31	10.9	37.8
March	6:52	7:03	12.2	48.6
April	6:00	7:38	13.6	60.1
May	5:24	8:09	14.8	68.4
June	5:15	8:29	15.2	71.6
July	5:33	8:19	14.8	68.5
August	6:04	7:41	13.6	60.1
September	6:36	6:49	12.2	48.7
October	7:09	5:59	10.8	37.3
November	7:47	5:25	9.6	28.1
December	8:14	5:22	9.1	24.7

**Data were collected on the 21st day of each month.*

5. After completing your graph, cut it on the line indicated on your Student Sheet and tape your graph to your partner's graph.
6. Draw a curve to smoothly connect the points on your combined graph.

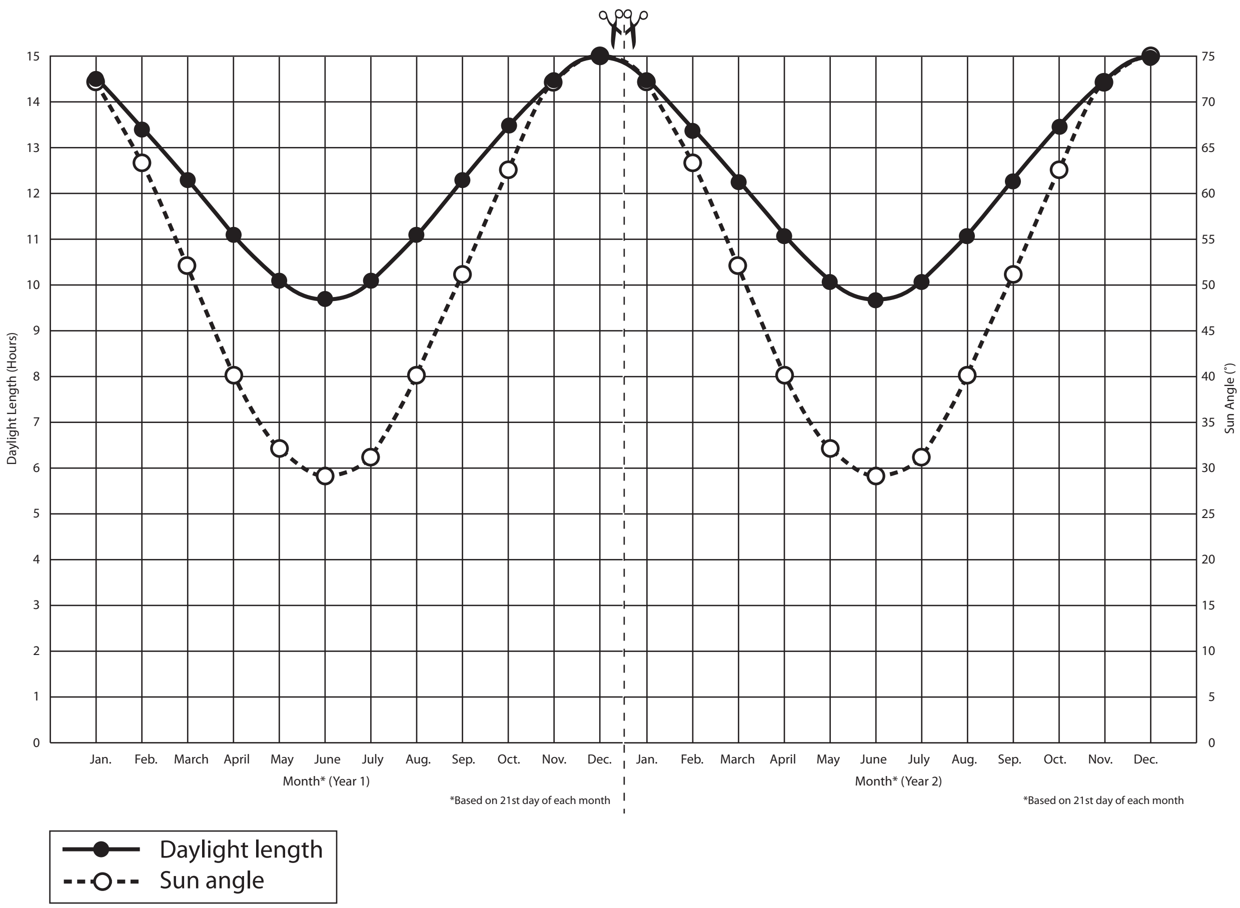
7. Create a key for the curves in your graph (noting which curve is which color).
8. Record in your science notebook the pattern you see now that you have graphed the data.
9. Discuss with your partner what the graph might look like if you added data for Year 3.

ANALYSIS

1. Based on your graph, what do you think was the length of daylight for each of the following days?
   a. March 6
   b. July 6
   c. November 6
2. When are the daylight hours
   a. shortest?
   b. longest?
   c. about equal to the length of the nighttime hours (12 hours)?
3. When is the Sun
   a. lowest in the sky?
   b. highest in the sky?
4. What is the relationship between the length of daylight and the Sun's angle?
5. How do the Sun's position in the sky and the length of daylight relate to the seasons of the year?

   Hint: Look at your graphs and compare the curves at March (beginning of spring), June (beginning of summer), September (beginning of fall), and December (beginning of winter).

6. In the following graph, data from the Southern Hemisphere were collected and graphed as you did in this activity for the Northern Hemisphere.
   a. What differences do you notice between your graphs and this graph?
   b. Are there any dates where the amount of daylight is the same in both the Northern and Southern Hemispheres?



7 A Year Viewed from Space

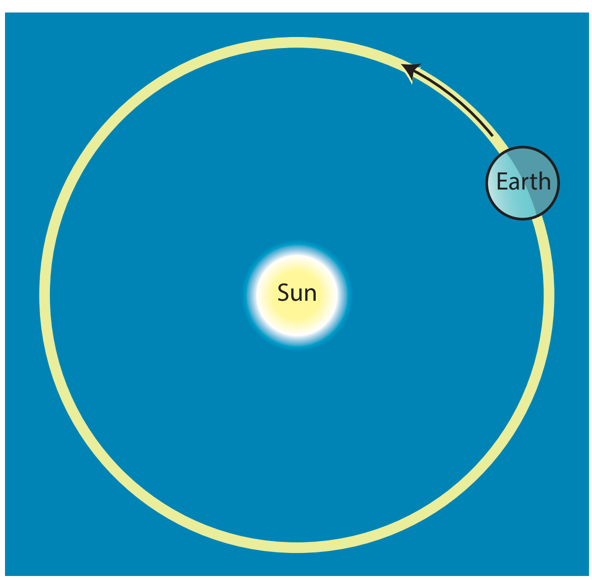
COMPUTER SIMULATION

A YEAR IS THE amount of time it takes Earth to complete one orbit around the Sun. Although the calendar shows 365 days in a year, Earth's year is actually about 365.24 days long. This is because Earth spins on its axis a little more than 365 times while making one complete orbit around the Sun. Earth's **axis** is the imaginary line passing through Earth's North Pole and South Pole. Each year on Earth, we observe patterns of changing temperatures, daylight hours, and seasons.

In this activity, you will use a computer simulation to model Earth's orbit around the Sun to help understand why we observe these patterns.

GUIDING QUESTION

What does Earth's orbit around the Sun have to do with seasons?



Diagrams like this one of Earth and its orbit around the Sun are much too small to show sizes and distances to scale, but they can help show how Earth orbits around the Sun.

MATERIALS

For each pair of students

1 computer with Internet access

For each student

1 Student Sheet 7.1, "Earth's Year Viewed from Space: Side View"

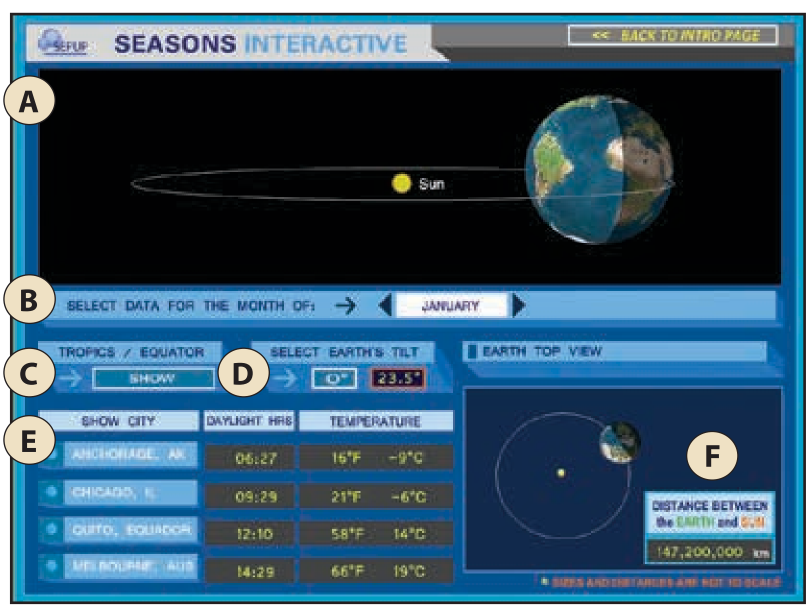
1 Student Sheet 7.2, "Earth's Year Viewed from Space: Top View"

PROCEDURE

Part A: Analyzing Data on Earth's Tilt and the Seasons

1. Open the Seasons Interactive Simulation, and review the introduction. Find each of the following on the screen:
   - North America and the United States
   - the Northern Hemisphere
   - the equator
   - the Southern Hemisphere
2. Begin the simulation by clicking in the "Continue to Interactive" box on the upper right of the screen. Find Earth and the Sun.

   Note: The size of Earth and the Sun, and the distance between Earth and the Sun, are not to scale.
3. Use the following diagram to find and set the six noted items on the screen:



A **EARTH SIDE VIEW** shows Earth and its orbit.

B **MONTH SETTING**: Use the arrows to move from month to month.

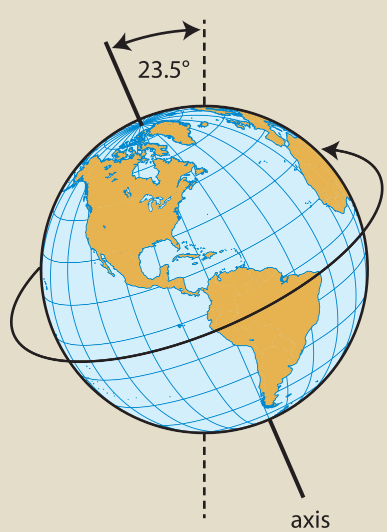
C **TROPICS/EQUATOR SETTING**: Make sure this is set to show.

D **EARTH'S TILT SETTING**: Make sure this is set to 23.5°, the actual tilt of Earth.

E **SHOW CITY BUTTONS**: Try clicking on each of these to see what happens. Then turn them all off.

F **EARTH TOP VIEW** shows Earth from above the North Pole in its orbit around the Sun.

4. Compare Student Sheet 7.1, "Earth's Year Viewed from Space: Side View," with the side view of the Sun and Earth at the top of your computer screen.
5. On the simulation, set the month for December, and click on the "Chicago, IL" button under "Show City."
6. Look at the top view and side view of Earth, and record each of the following on Student Sheet 7.1 for December in Chicago:
   - the position of Earth and direction of its tilt
   - the number of daylight hours



Earth's tilt refers to the fact that Earth's axis is not perpendicular or parallel to Earth's orbital plane around the Sun. Earth's axis is actually tilted about 23.5 degrees from perpendicular.

7. Repeat Step 6 three more times: once for March, once for June, and once for September.
8. What do you think the number of daylight hours for Chicago would be in December, March, June, and September if Earth had 0 degrees (°) of tilt? Record your ideas in your science notebook.
9. Change the tilt to 0 degrees, and then describe what happens to daylight hours and temperature in Chicago as you change the months of the year and as Earth orbits around the Sun.
10. Return the tilt to 23.5 degrees. Now click on "Melbourne, Aus." Notice that Melbourne is in the Southern Hemisphere. Explore its daylight hours as you change the months. In your science notebook, record the following:
    - Melbourne's average daylight length in December and June
    - Melbourne's average temperature in December and June

Part B: Analyzing Data on the Earth-Sun Distance

11. In the simulation, look at the "Earth Top View." Notice how the distance from Earth to the Sun is displayed in kilometers at the bottom right corner.
12. Many people claim that Earth's seasons are caused by changes in Earth's distance from the Sun during different times of year. Write down whether you agree or disagree with this claim in your science notebook. Discuss why you agree or disagree with your partner.
13. Set the month to December, the beginning of winter in the Northern Hemisphere. Record the distance from Earth to the Sun and the average temperature in the appropriate spaces on Student Sheet 7.2, "Earth's Year Viewed from Space: Top View."
14. What do you think the distance from Earth to the Sun will be at the start of spring (March)? of summer (June)? of fall (September)? Discuss your predictions with your partner.
15. Repeat Step 13 for March, June, and September. With your partner, discuss whether the data support or go against your predictions.

ANALYSIS

1. In what month is the Northern Hemisphere most tilted toward the Sun?
2. In what month is the Northern Hemisphere most tilted away from the Sun?
3. Using what you learned from the computer simulation, explain how Earth's tilt affects the seasons and daylight length.
4. Does Earth's tilt change over the course of a year? Explain.
5. In which month(s) is Earth
   a. closest to the Sun?
   b. farthest from the Sun?
6. Based on what you have observed about the distance from Earth to the Sun, does the distance from Earth to the Sun determine the seasons? Explain using evidence from this activity.

EXTENSION

Graph the daylight length vs. month for one of the cities presented in the simulation or for your city in the United States. Compare it to the graph you did in the "Changing Sunlight" activity. How are the graphs similar? How are they different?

8 Earth's Tilt

MODELING

In the last activity, you used a computer simulation to investigate why there are seasons on Earth. Like any model, the simulation has some strengths and weaknesses. It shows the orbit and tilt of Earth to help you understand the seasons. But it doesn't show the correct relationship between the size of Earth and the Sun or the distance between them. It also might give you the incorrect idea that Earth's tilt causes one hemisphere to be much closer to the Sun.

In this activity, you will take a closer look at why Earth's tilt is related to the seasonal changes on Earth.

This globe, called the Unisphere, was built for the 1964 World's Fair in Queens, New York. Like most globes, it shows Earth's tilt.

GUIDING QUESTION

Why does Earth's tilt cause different places on Earth to receive different amounts of energy from the Sun?

MATERIALS

For each group of four students

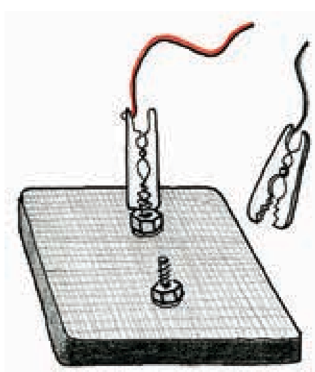
1 solar cell
1 electric motor with flag on axle
2 wire leads with alligator clips (1 red wire and 1 black wire)

For each student

1 Science Skills Student Sheet 7, "Analyzing Models"

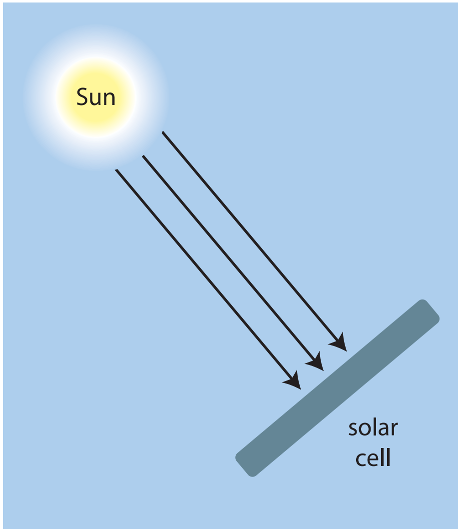
PROCEDURE

1. Following your teacher's instructions, complete Science Skills Student Sheet 7, "Analyzing Models." Make sure to explain all parts of the model: the solar cell, sunlight, and the motor.
2. Work with your group to connect the solar cell to the electric motor with the wires.

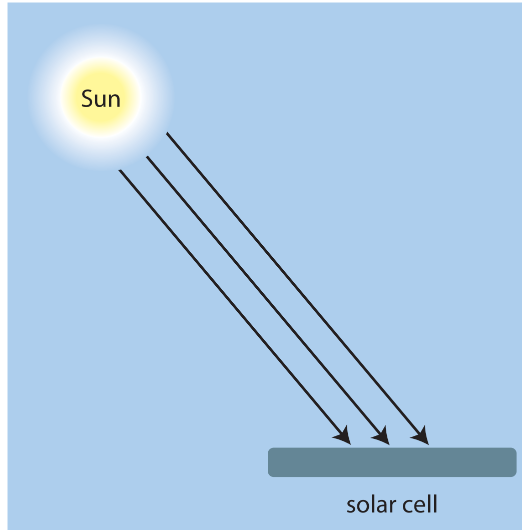


Back of solar cell

3. Hold the solar cell so it directly faces the Sun, as shown in Position A on the next page. Observe what happens to the motor and record in your science notebook.
4. Gradually tilt the solar cell so that it still gets sunlight but does not directly face the Sun, as shown in Position B on the next page. Observe what happens to the speed of the motor and record in your science notebook.



Position A



Position B

ANALYSIS

1. When you tilted the solar cell from Position A to Position B, what effect did it have on the speed of the motor attached to the solar cell?
2. What does your answer to Analysis item 1 tell you about the amount of the Sun's energy transferred to the solar cell in the two different positions? Be sure to give a complete explanation.
3. Why is the Northern Hemisphere warmer when it is tilted toward the Sun?
4. Why is it summer in December and winter in July in the Southern Hemisphere? Explain using evidence from this activity.
5. **Reflection**: How did each of the following system models help you understand how Earth's tilt causes the seasons?
   - the computer simulation
   - the globe and flashlight model
   - the solar cell and motor model

9 Earth on the Move

READING

YOU HAVE BEEN using models to observe and gather data about Earth's tilt and Earth's orbit around the Sun. But even with the use of models, it can still be hard to understand what causes seasonal changes on Earth. This activity will give you the chance to think more deeply about these phenomena.

GUIDING QUESTION

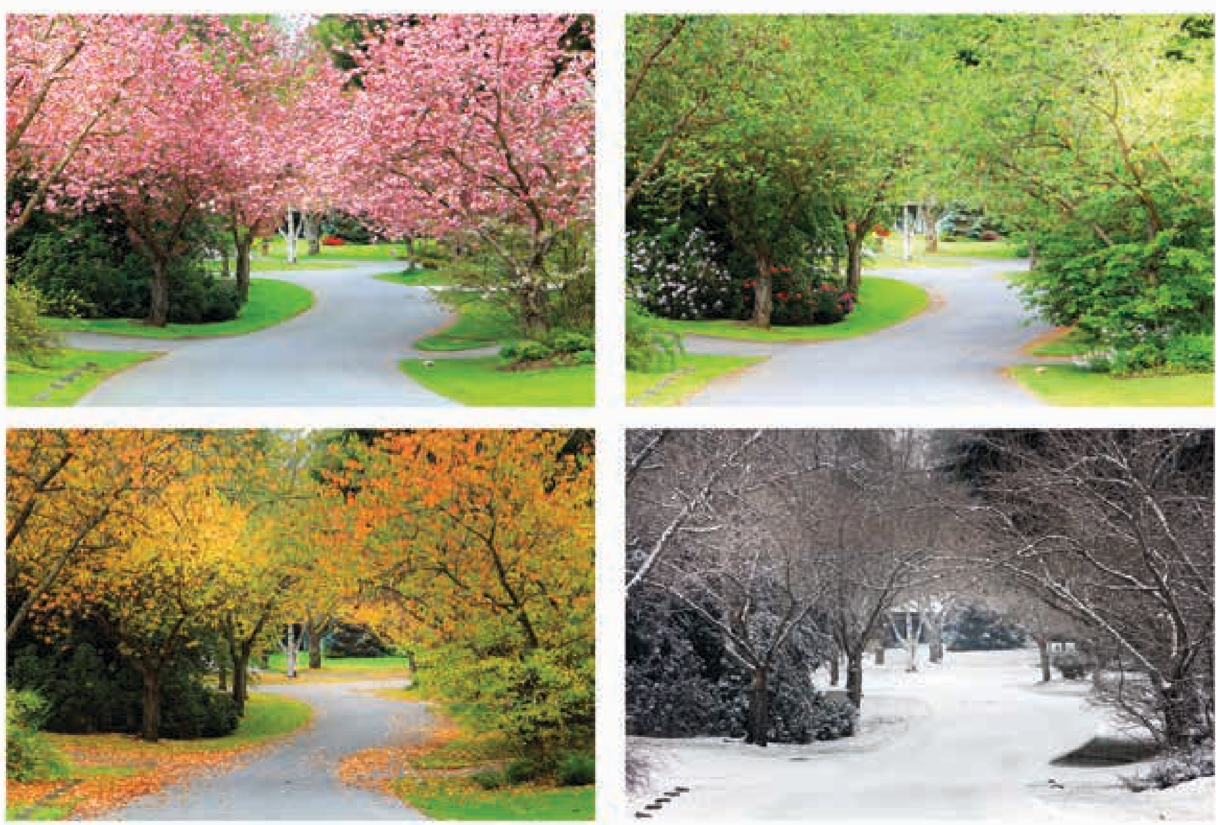
Why does Earth have seasons?

MATERIALS

For each student

1 Student Sheet 9.1, "Three-Level Reading Guide: Earth on the Move"

1 Student Sheet 6.1, "Anticipation Guide: Sunlight and Seasons" (started)



These photographs show seasonal changes observed at the same location over the course of a year.

Earth viewed from space in July. Compare the amount of snow in the Northern and Southern Hemispheres in this photo to the photo on the next page.

READING

Use Student Sheet 9.1, "Three-Level Reading Guide: Earth on the Move," to guide you as you complete the following reading.

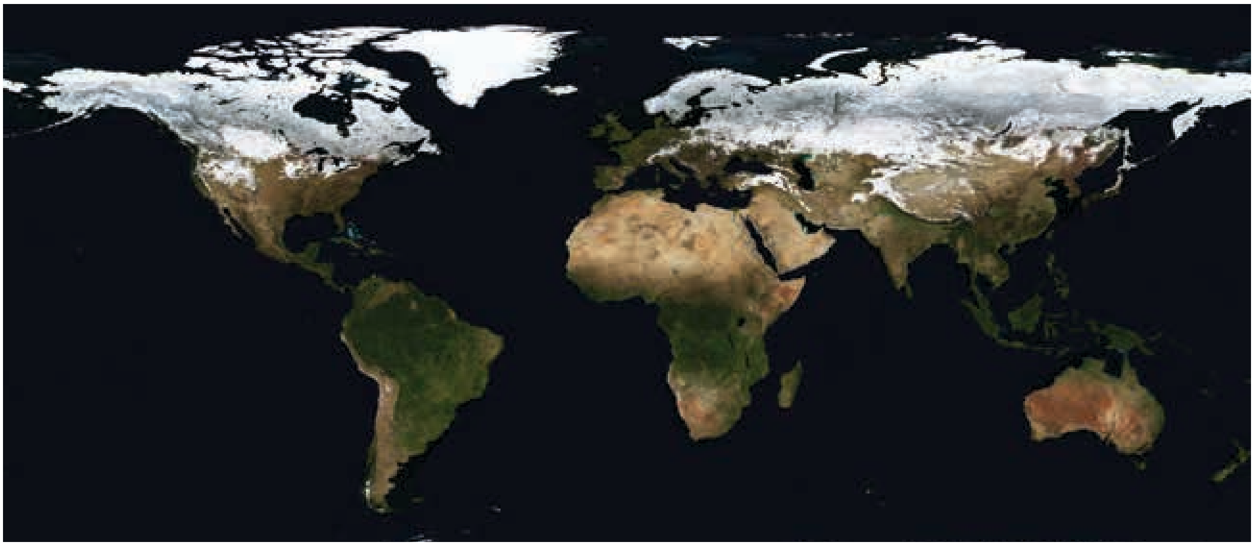
Earth's Year and the Seasons

To understand seasons, you must consider both Earth's orbit around the Sun and Earth's tilt.

Some people think that seasons are caused by changes in the distance between Earth and the Sun. This explanation seems possible since Earth's orbit is not a perfect circle. That means that Earth's distance from the Sun changes during the year. However, Earth's changing distance from the Sun doesn't cause the seasons.

The computer simulation in the activity "A Year Viewed from Space" showed that Earth is about 6 million km closer to the Sun in December than it is in June. If closeness of Earth to the Sun caused the seasons, both the Northern and Southern Hemispheres would have winter in June and July and summer in December and January.

If the seasons are not caused by changes in Earth's distance from the Sun, what causes them? The computer simulation showed that the seasons are related to Earth's tilt. During the time of year when the Northern Hemisphere (which includes the United States) is tilted toward the Sun, it experiences summer. The seasons in the Southern Hemisphere are opposite from the seasons in the Northern



Earth viewed from space in January. Compare this with the photo on the facing page. Notice that there is more snow in North America (located in the Northern Hemisphere) but less snow in the mountains of South America (located in the Southern Hemisphere), where it is summer in January.

Hemisphere. This is because the Southern Hemisphere is tilted away from the Sun when the Northern Hemisphere is tilted toward the Sun. This is shown in the following diagram. Australia and much of South America and Africa have winter from June through September, when the United States has summer.

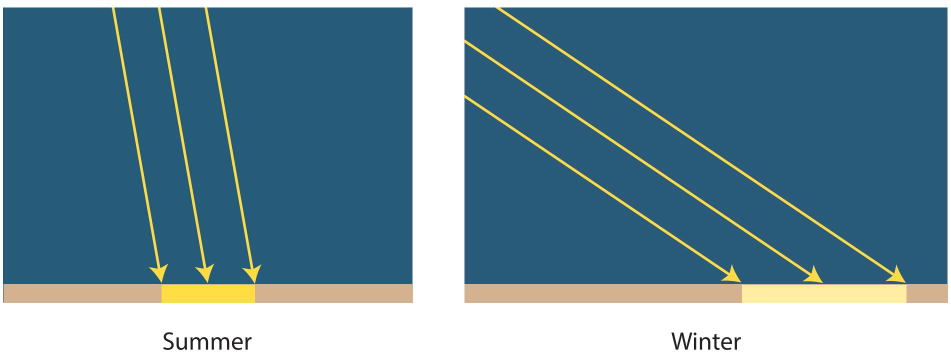
Earth's Tilt and the Angle of the Sun

Why does Earth's tilt make such a difference? There are two reasons. The first reason is that the tilt causes parts of Earth's surface to receive more-direct sunlight than other parts.

During summer, you will notice that the Sun's angle above the horizon at noon is higher than the Sun's angle above the horizon at noon during winter. The higher the angle of the Sun, the more direct the sunlight is on that part of Earth's surface. Since that part of Earth's surface is receiving more-direct sunlight than other parts of Earth's surface, it heats up more.

This diagram shows that when one hemisphere is tilted toward the Sun, the other is tilted away from the Sun. (Size and distance are not to scale.)

You observed this effect of the Sun's angle on energy transfer when you used the solar cell. You compared the amount of energy transfered to the solar cell when it was directly facing the Sun to when it was tilted relative to the Sun. You noticed that the motor slowed down as you tilted the solar cell from directly facing the Sun to an angle less directly facing the incoming sunlight. When you did this, you were modeling the change in the angle of the sunlight from summer to winter. The following diagram shows why the angles of sunlight hitting Earth's surface in summer and winter affect the amount of energy transferred to a location on Earth's surface.



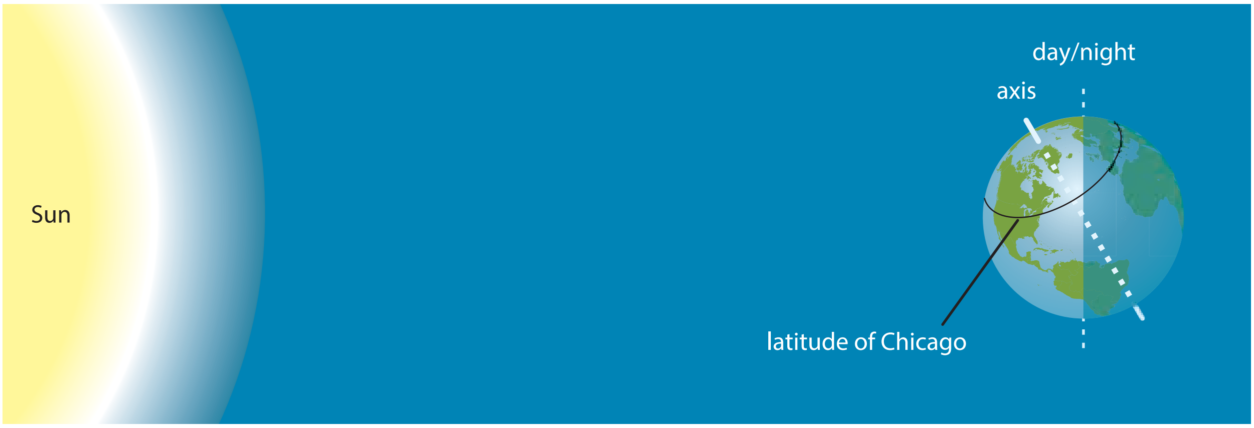
When sunlight strikes Earth's surface at a lower angle, as on the right, the Sun's energy is more spread out.

Earth's Tilt and Daylight Length

The second reason why Earth's tilt makes such a difference is its effect on the length of daylight. The Sun is up for more than 12 hours every day during the summer and for less than 12 hours every day during the winter. As you observed in the "Changing Sunlight" activity, the longest day of the year marks the beginning of summer, and the shortest day of the year marks the beginning of winter. The parts of Earth tilted toward the Sun have longer days so there is more time for the Sun's energy to heat Earth's surface than when those parts of Earth are tilted away from the Sun. The diagram on the next page shows how Earth's tilt can affect the amount of daylight hours at a given location.

If Earth were not tilted, most places would have very little difference in average daily temperature over the year, and the Sun would be out for 12 hours every day. You observed this in the computer simulation when you set Earth's tilt to 0 degrees.

If Earth had a larger tilt, the difference in temperature and daylight hours between summer and winter would be more extreme.



In the summer, the city of Chicago's day is longer than its night because the Northern Hemisphere is tilted toward the Sun. (Sizes and distances are not to scale.)

ANALYSIS

1. Prepare a labeled diagram that includes a caption to explain how Earth's tilt and its orbit around the Sun cause each of the following:
   a. changes in the angle of sunlight hitting Earth's surface.
   b. the seasons in the Southern Hemisphere to be opposite the seasons in the Northern Hemisphere.
2. In the Northern Hemisphere, the four seasons in a calendar year are in the order of winter, spring, summer, fall. The seasonal cycle then begins to repeat with winter near the end of the calendar year.
   a. What order are the seasons in the Southern Hemisphere during a calendar year?
   b. Explain how your answer to 2a provides evidence against the claim that seasonal changes are due to Earth's distance from the Sun.
3. The Cassini mission sent a spacecraft to Saturn. One of the goals of the mission was to learn more about the seasonal changes observed on Saturn. Even though Saturn receives about 1% of the amount of sunlight on its surface as Earth receives, it still has seasons. Why do you think Saturn has seasons?
4. **Reflection**: Review your initial ideas about the seasons that you recorded on Student Sheet 6.1, "Anticipation Guide: Sunlight and Seasons." How have your ideas about the cause of seasons changed since you began this unit? Complete Student Sheet 6.1 with your new understanding.

10 Observing Objects in Space

INVESTIGATION

WHILE WE ARE able to make observations of the Sun and Moon during the day, most astronomers spend their time observing objects in space at night. An **astronomer** is a scientist who studies objects and events beyond Earth's atmosphere, such as the movement of stars and planets. The difficulty in understanding these other objects in space is that everything appears to be so small from our perspective on Earth. Because of this, astronomers and engineers have worked together to create new technologies, like telescopes and spacecraft, to help us make more-detailed observations of space objects.

In this activity, you will further investigate objects in space, mostly those found in our Solar System. A **solar system** is a star and all of the objects that orbit around it. Our Solar System, with its one star, the Sun, and the planets, asteroids, and planetary moons that travel around it, is just one tiny part of our Galaxy. Our Galaxy, the Milky Way, is only one of billions of galaxies.

GUIDING QUESTION

What types of objects are found in space?

MATERIALS

For each group of four students

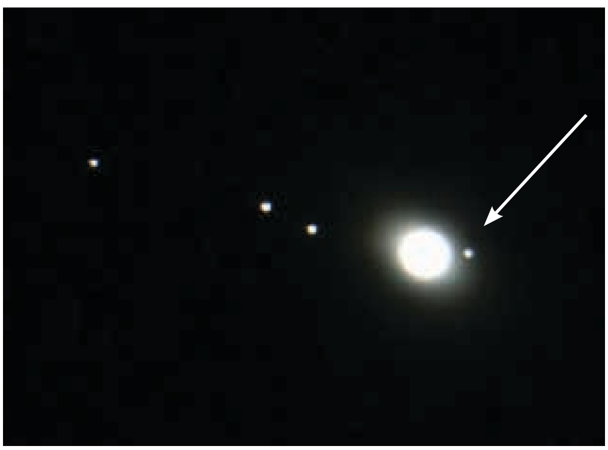
1 set of 6 Space Object Cards

PROCEDURE

1. Each photograph on the next page shows a space object as seen through a camera from Earth.
2. Carefully examine each space object, and think about what it might be. For example, a space object could be a moon, a star, a planet, a galaxy, an asteroid, a comet, an artificial satellite, or something else.
3. In your science notebook, write down
    a. what you think each object might be.
    b. an order of the objects from smallest to largest.
    c. an order of the objects from closest to Earth to farthest from Earth.
4. Discuss your observations and ideas with your partner.
5. In your group, take turns looking at the picture on each of the Space Object Cards. Each of the objects on the Space Object Cards was photographed by a spacecraft or through a powerful telescope. Do not read the back of the cards at this time.
6. In your group, match each card to one of the space objects shown on the next page.
7. Read the descriptions on the back of each Space Object Card.
8. Add the information from your cards to what you wrote down in Step 3. Revise your ordered lists if you need to.

1

2



3

4

5

6

ANALYSIS

1. Were you able to identify any of the space objects before seeing the Space Object Cards? If so, which ones?
2. Did seeing larger and clearer images on the Space Object Cards help you identify some of the space objects? Explain.
3. How did the Space Object Cards help you in Step 8?
4. Astronomy is the oldest science, dating back tens of thousands of years. However, astronomers didn't even know all of the planets in the Solar System until the 1800s. Why do you think that is?
5. How much farther away from the Sun is the farthest space object than the closest space object?

   Hint: Divide the distance to the farthest object by the distance to the closest object.
6. What are some trade-offs between looking at an object from Earth and sending a spacecraft to investigate the object?

EXTENSION

On a clear night, go outside and find a place where you have a good view of the sky and you are as far away from any lights as possible. Look carefully at the night sky, and find five bright, but different, objects. Use the following information to guide your observations. Record your observations as instructed by your teacher. Look at those same objects on five different nights, and identify how they have changed.

Field Study of the Night Sky

The objects described below are visible with the "naked eye" and can usually be seen on a dark, clear night away from city lights.

STARS are the most common object we see in the night sky. The light from a star comes from so far away that it appears to be a single point of light. Stars seem to "twinkle" because Earth's atmosphere refracts, or redirects, some of the light. Some stars can appear as different colors, such as red, white, or blue. Stars appear to move together across the sky at night.

PLANETS may be difficult to distinguish from stars. If an object in the sky looks like a star but doesn't twinkle as much, it is likely to be a planet. Planets can appear to be different colors. Planets appear as disks when magnified with binoculars or a telescope. Although much smaller than stars, they can appear larger because they are much closer to Earth.

EARTH'S MOON looks like the largest object in the night sky because it is the closest object to Earth. The phase of the Moon changes from night to night. Other planets have moons, but they are too small or too distant for us to see without a telescope.

SATELLITES move quickly across the night sky. Many satellites are seen only around sunrise or sunset. Most satellites take about 90 minutes to orbit Earth.

METEORS are small, bright objects that speed across the sky for a few seconds and appear to leave a trail. Meteors are often mistakenly called "shooting stars" or "falling stars," but they are not stars at all. Meteors are pieces of rock that are falling through the atmosphere and usually burn up before they hit the ground. Meteors that reach Earth's surface are called *meteorites*.

GALAXIES are collections of billions of stars. Only a few galaxies can be seen with the naked eye because most are too far away. To see what a galaxy looks like, look at the Andromeda Galaxy pictured in this activity.

11 Drawing the Solar System

MODELING

When you look into the night sky, most of the objects other than the Moon appear to be about the same size. They also look like they could all be the same distance from Earth. They are neither. Although early astronomers' observations gave people some idea of how big and how far away the planets in the Solar System are, it took the invention of telescopes, satellites, and rockets to make accurate measurements.

In this activity, you will use a **scale**—a ratio of the size of a real object to the size of a model of that object—to turn scientific measurements into an accurate model showing the distances of the planets in our Solar System from the Sun.

GUIDING QUESTION

How can a scale model help us understand distances between objects in our Solar System?

A scale model, such as this one of a building, can help people visualize the proportions of something that is too large or too small to study directly.

MATERIALS

For each pair of students

1 calculator

For each student

1 Student Sheet 11.1, "The Size of the Solar System"

1 Student Sheet 11.2, "The Sizes of the Planets"

1 Student Sheet 11.3, "Scaled Sun-to-Planet Distances"

1 ruler

PROCEDURE

Use Student Sheet 11.1, "The Size of the Solar System," and Student Sheet 11.2, "The Sizes of the Planets," to prepare you for this and the next activity.

Part A: Distances in the Solar System

1. Using the data in the "Planets' Distance from the Sun" table below and a scale of 1 centimeter (cm) = 200,000,000 km, calculate the relative distances of the planets from the Sun.

   Hint: To calculate the distance in centimeters, you will need to divide a planet's distance from the Sun in kilometers by the scale.

Planets' Distance from the Sun

PLANET	APPROXIMATE DISTANCE FROM THE SUN (km)
Mercury	58,000,000
Venus	108,000,000
Earth	150,000,000
Mars	227,000,000
Jupiter	778,000,000
Saturn	1,429,000,000
Uranus	2,869,000,000
Neptune	4,505,000,000

2. Record the results of your calculations in the table on Student Sheet 11.3, "Scaled Sun-to-Planet Distances." Round your answers to the nearest 0.1 cm.

3. Using the values you just calculated, draw a scale model of the distances on Student Sheet 11.3.

   a. Measuring from the center of the Sun, draw an **X** on the line where each planet is located.

   b. Record the name of each planet next to its location on the line.

Part B: Diameters of the Planets in the Solar System

4. Look at the diameters of the planets shown in the "Planets' Diameters" table below.

Planets' Diameters

PLANET	APPROXIMATE DIAMETER (km)
Mercury	5,000
Venus	12,000
Earth	13,000
Mars	7,000
Jupiter	143,000
Saturn	120,500
Uranus	51,000
Neptune	49,500

5. In your group, discuss whether the same scale used in Part A can be used to create a scaled drawing of each planet's diameter.

   Hint: To calculate the diameter in centimeters, you will need to divide a planet's diameter in kilometers by the scale in kilometers (1 cm = 200,000,000 km). Round your answers to the nearest 0.1 cm.

6. With your group, discuss whether the following image of the Solar System is scaled properly. Use your group's response from Step 5 to inform your discussion. Record your ideas in your science notebook.

ANALYSIS

1. Astronomers often measure distances in the Solar System using a unit called the *astronomical unit* (au). 1 au is about 150,000,000 km—the mean, or average, distance between Earth and the Sun.
   a. Why do you think the astronomical unit is used to measure distances in the Solar System?
   b. Why do you think the astronomical unit is not used to measure distances on Earth?
2. Scientists use scale models to study systems that are really large or really small.
   a. How did the scale model you drew help you better understand distances in the Solar System?
   b. What are the challenges of creating a scale model of the Solar System that shows planet size and distance?
3. **Reflection**: Now that you have looked at the distances between planets, why do you think it is so challenging to travel to other places in our Solar System?

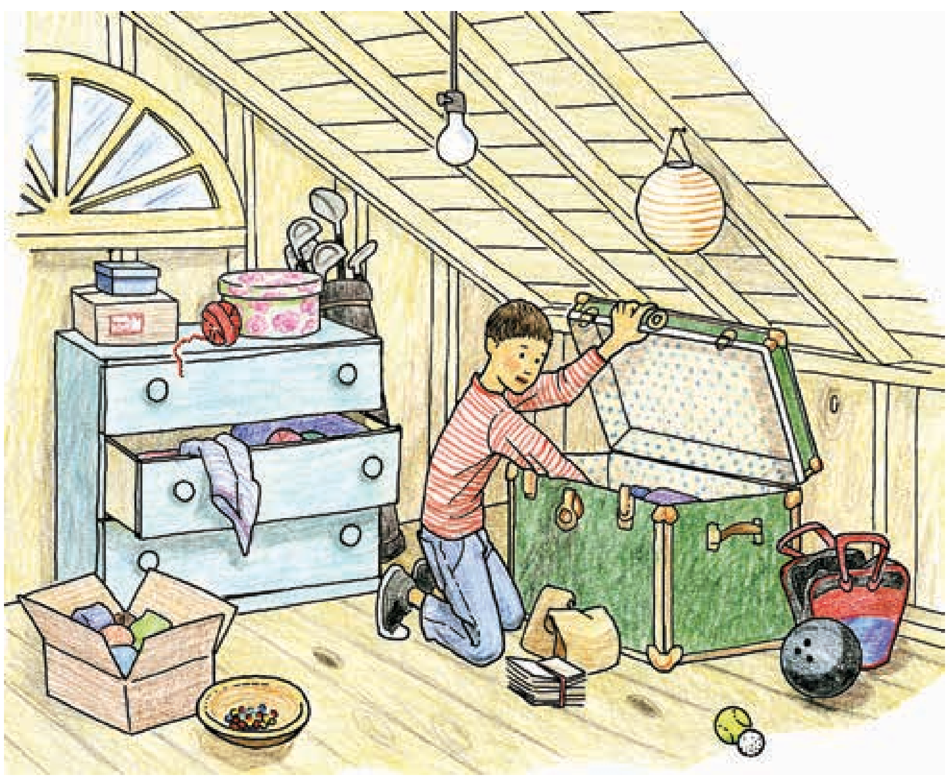
12 How Big are the Planets?

PROJECT

I N THE PREVIOUS activity, you drew a scale model of the distances between the Sun and the planets in our Solar System. On the same model, the scaled size of Earth would be much too small to see. We need to use a different scale when comparing the sizes of the different planets in our Solar System.

GUIDING QUESTION

How can you make a scale model showing the sizes of all of the planets?



Scale models can be made using objects found at home.

MATERIALS

For each group of four students

9 or 10 spherical objects of varying sizes

1 meter stick

1 calculator

1 set of colored pencils

For each student

1 compass

1 Student Sheet 11.2, "The Sizes of the Planets" (completed)

1 Student Sheet 12.1, "Scaled Sizes of the Planets"

PROCEDURE

Part A: Determining a Scale

1. In your science notebook, copy the "Diameters of the Planets" table that is shown below.

Diameters of the Planets

Planet	Approximate diameter (km)	Scaled diameter (cm)	Diameter of model object (cm)	Calculated percent error
Mercury	5,000			
Venus	12,000			
Earth	13,000			
Mars	7,000			
Jupiter	143,000			
Saturn	120,500			
Uranus	51,000			
Neptune	49,500			

2. With your group, decide on a scale for the diameter of the planets. You will use this scale to find objects that represent the size of the planets in the model. Complete Steps 2a–e to make the scale.

   a. Decide how many kilometers a single centimeter will represent. This is the scale.

   b. Convert the diameters of the smallest and largest planets using the scale.

   Hint: Divide the diameter in kilometers by the scale in kilometers to get the diameter in centimeters. (How many kilometers will equal 1 cm in your scale?)

c. If either of the scaled diameters is too big or too small for the ordinary spherical objects you have access to, try creating another scale.

d. Repeat Steps 2a–c until the group agrees that the scale for the size of the smallest and largest planets is reasonable.

e. Record the scale in your science notebook.

3. Using the scale you made and the data in the table, calculate the scaled diameters of all the planets. Record these in your table.

Part B: Making the Model

4. With your group, use your work from Part A to create accurate models of the planets using round objects you find at home and school. Gather objects with diameters that are similar to the scaled diameters you recorded in Step 3.

5. Measure the actual diameters of the objects, and record them in your table.

6. Using the following equation, determine the percent error between each model planet's measured diameter and that planets scaled diameter. This percentage will help you determine how precise your scale is in representing the actual diameter of the planets. A percentage closer to zero is more precise.

$$\%\ \text{error} = \frac{(\text{scaled diameter} - \text{diameter of model object})}{\text{scaled diameter}} \times 100\%$$

7. With your group, prepare a presentation of your model. Make sure your presentation explains

- the scale you used.
- which object models which planet.
- any inaccuracies in your model.

ANALYSIS

1. Which planet in your model is most accurate to your scale? Which planet is least accurate? Explain your reasoning.
2. The diameter of the Sun is about 1,390,000 km.
   a. Convert the Sun's diameter to the scale of your model.
   b. Are there any objects that could be used in your model to represent the Sun? Give an example or explain why not.
3. Complete Student Sheet 12.1, "Scaled Sizes of the Planets," using a different-colored pencil for each planet.
   a. Find a scale that allows you to accurately draw the smallest and largest planets on the paper.
   b. Record the scale on Student Sheet 12.1.
   c. Convert all the diameters of the planets to the scale. Record them in the table.
   d. Use a compass to draw the scaled planets as circles inside circles with all planet centers being Point C. To draw each planet, adjust the compass to one half the planet's scaled diameter.
   e. Label each planet with its name.
4. Mercury, Venus, Earth, and Mars are all rocky planets. Jupiter, Saturn, Uranus, and Neptune are gaseous planets. Looking at Student Sheet 12.1, what similarities and differences do you notice between the two types of planets?
5. **Reflection**: How did your understanding of the relative sizes of planets change as you completed this activity? Refer to your drawings on Student Sheet 11.2, "The Sizes of Planets," and Student Sheet 12.1.

EXTENSION

With your class, make a physical model of the Solar System that shows both the Sun-to-planet distances and the sizes of the planets.

13 Identifying Planets

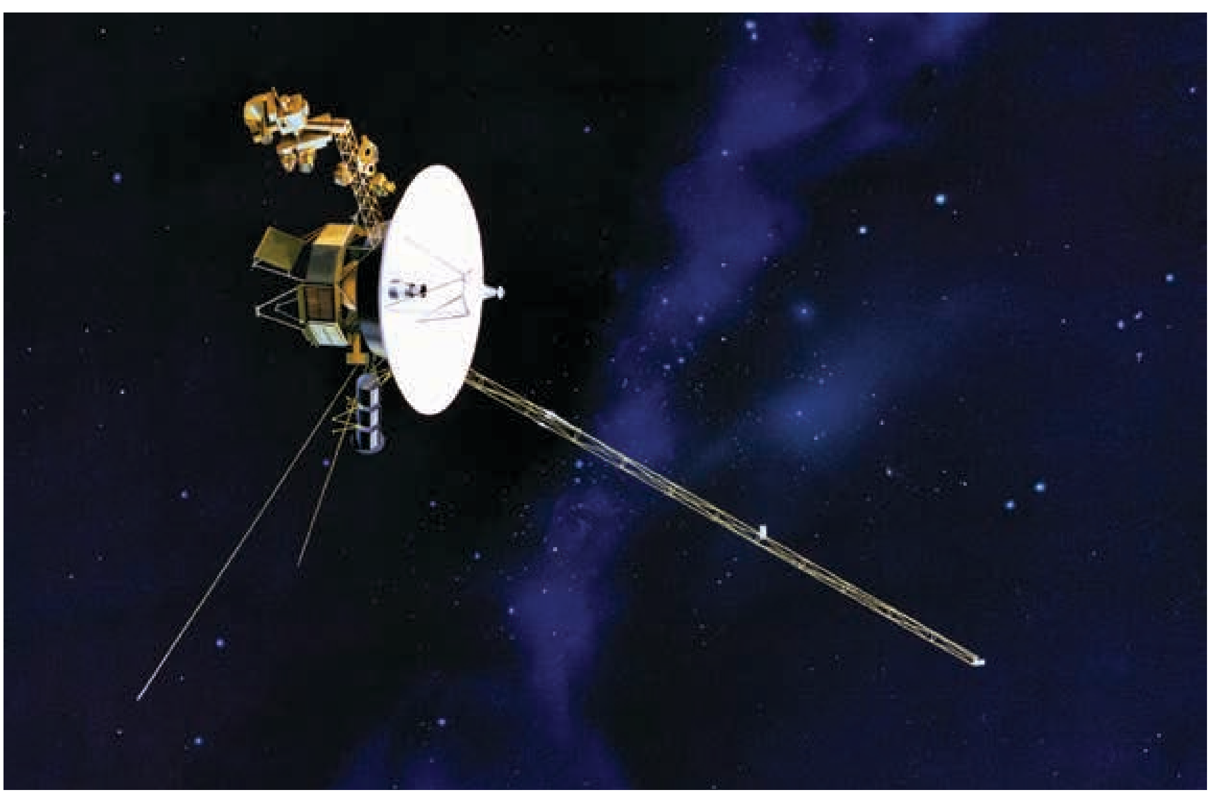
INVESTIGATION

FROM PREVIOUS ACTIVITIES, you know that there are huge distances between the planets in our Solar System. Using only telescopes and math, astronomers have figured out how far it is from Earth to these different space objects. The measurements have been so precise that scientists have used them to successfully send spacecraft to each of the planets in our Solar System to gather data for research. These space missions to other planets have allowed us to make more-detailed observations than ever before.

In this activity, you will analyze and interpret data received from a few different spacecraft traveling in our Solar System. The goal of your analysis is to figure out which planet each spacecraft is observing.

GUIDING QUESTION

What features make each planet in our Solar System unique?



This is an image of Voyager 1. This spacecraft took the first ever portrait of the Solar System. The portrait was taken at a distance of more than 6 billion km (4 billion miles) from Earth!

MATERIALS

For each pair of students

1 calculator

For each student

1 Student Sheet 13.1, "Planet Information"

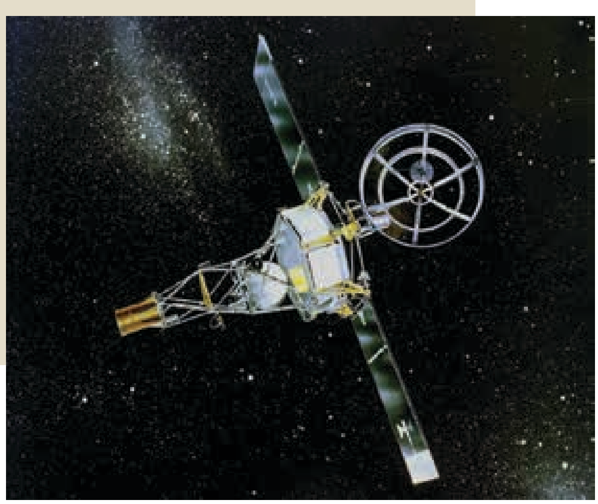
PROCEDURE

1. Read the following four transmissions of information from the different spacecraft.
2. Choose one of the transmissions, and carefully compare the descriptions in it with the information provided on Student Sheet 13.1, "Planet Information."

   Hint: It can be helpful to add marks to Student Sheet 13.1 to any planet that meets the description of the transmission.
3. With your partner, decide from which planet the transmission was sent.
4. In your science notebook,
   - record the name of the spacecraft that sent the transmission and the name of the planet it was visiting.
   - list the evidence in the transmission that helped you decide which planet the transmission came from.
5. Repeat Steps 2–4 for the other three transmissions.

Transmission from Mariner 2

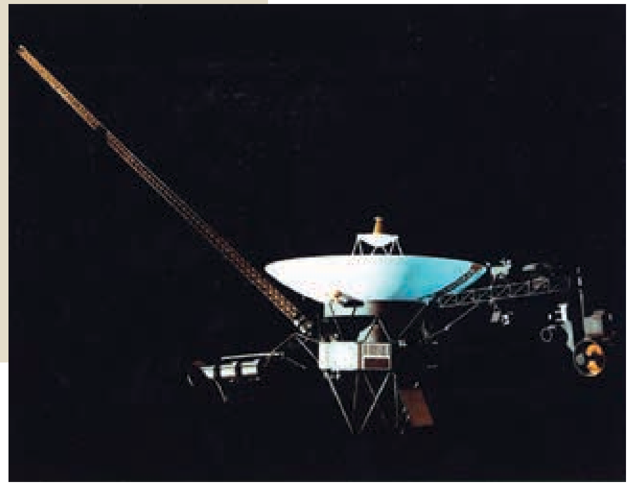
This planet's mass is very similar to Earth's mass. It takes over 7 Earth-months for this planet to complete an orbit around the Sun. The average temperature here is much hotter than Earth's average temperature.



Scientists measured the temperature of this planet's atmosphere for the first time during the Mariner 2 mission.

Transmission From Voyager 2

The diameter of this planet is about four times as large as Earth's diameter, and it takes over 50 Earth-years to orbit the Sun. The temperature of this planet is much lower than Earth's average temperature. More than 20 moons orbit this planet, and this planet has rings.



The Voyager 2 spacecraft was the first to visit this planet. While there, it discovered 10 new moons.

Transmission From MESSENGER

There are only two planets that ever get closer to Earth than this one. While its surface temperature is hot, it is not the hottest planet in the Solar System. This planet does not have any rings.

The MESSENGER mission discovered frozen water at the planet's north pole.

Transmission From Juno

This gaseous planet has rings and is colder than Mars but warmer than Uranus. Its diameter is about three times as large as the diameter of Neptune. This planet also has many moons.

On a close fly-by of this planet, the Juno spacecraft discovered that there are huge cyclone storms in the atmosphere at the poles. Some are 1,400 km wide!

ANALYSIS

1. Write a transmission from a planet in our Solar System other than those already used in this activity. In your transmission, describe several features that would help someone else identify the planet.
2. Look at the following "Pluto's Properties" table. It contains data related to the dwarf planet Pluto. Analyze the data by comparing Pluto with the planets on Student Sheet 13.1, and then answer the following questions:
   a. What are the similarities and differences between Pluto and the rocky planets in the Solar System?
   b. What are the similarities and differences between Pluto and the gaseous planets in the Solar System?
   c. Calculate the scaled sizes of Pluto, Earth, and Jupiter using a scale of 2,374 km = 1 cm.
   d. Look at your answers for 2a–c. Why do you think Pluto is not considered a planet?

PLUTO'S PROPERTIES

Distance from Sun (au)	39.5
Mass (10^{24} kg)	0.0013
Time to complete one orbit (years)	248
Diameter (km)	2,374
Average temperature (°C)	–229
Number of moons	5
Has rings	Maybe
Composition	Rocky and icy

3. **Reflection**: The surface of Mars has a very rocky and uneven terrain. When designing the Mars Exploration Rovers, scientists and engineers at NASA created a large test area with rock, soil, and sand that matched images of Mars's surface. Engineers working on this mission used the area to test their designs for the wheel systems of the rovers. The rovers were only expected to drive around and collect data on the planet for about 90 days. But both remained operational for several years and drove much farther than expected! How do you think the work of the engineers supported this mission's scientific goals?

14 Gravitational Force

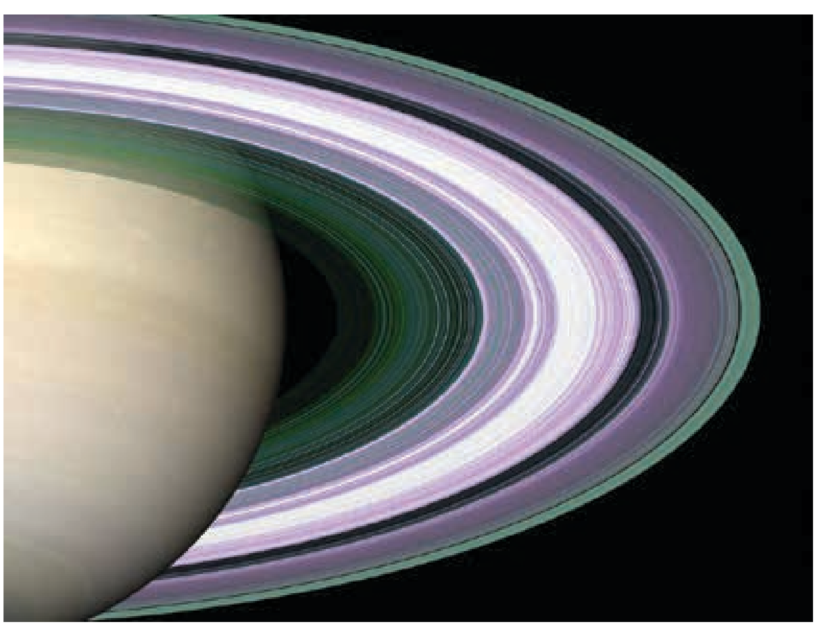
INVESTIGATION

SPACE MISSIONS HAVE allowed us to learn a lot about our Solar System. Every mission has many challenges to overcome in order to succeed. A big challenge for every space mission is dealing with gravity. **Gravity** is a natural phenomenon that causes objects to be pulled toward each other. **Gravitational force** is the amount of gravitational pull between two objects. Spacecraft must overcome the gravitational force between it and the Earth in order to launch into space. Long before the first spacecraft launched into orbit, Sir Isaac Newton figured out that the gravitational force between two objects depends on the distance between the objects and the mass of each object. **Mass** is the measurement of the amount of matter, or stuff, in an object.

In this activity, you will analyze gravitational force data collected from Saturn's rings to better understand how the force of gravity is related to the mass of objects and the distance between them.

GUIDING QUESTION

What determines the amount of gravitational force between objects?



Although they look solid from Earth, Saturn's rings are actually made up of a large number of small objects that orbit Saturn due to gravity.

MATERIALS

For each student

1 sheet of graph paper
1 ruler

PROCEDURE

Part A: Gravitational Force on Different Masses

1. The "Mass and Gravitational Force Data" table shows the gravitational force between Saturn and some objects in Saturn's rings. All of the objects are the same distance (180,000 km) from Saturn's center.

Mass and Gravitational Force Data

MASS OF RING OBJECT (kg)	GRAVITATIONAL FORCE BETWEEN SATURN AND RING OBJECT (IN 10,000 N)
2	23
3	35
4	47
5	58
6	70
7	82
8	93
9	105

2. Use the data in the table to make a graph of the relationship between the ring object's mass in kilograms (kg) and gravitational force in newtons (N). Label your graph "Gravitational Force vs. Mass."

   Note: Put the data for mass on the horizontal axis and the data for gravitational force on the vertical axis.

3. Look at your graphed data, and record in your science notebook any relationships you notice.

Part B: Gravitational Force at Different Distances

4. The "Distance and Gravitational Force Data" table shows the gravitational force between Saturn and some ring objects that are at different distances from the planet. All of the objects in this table have a mass of 1 kg.

Distance and Gravitational Force Data

DISTANCE OF RING OBJECT FROM CENTER OF SATURN (IN 1,000 km)	GRAVITATIONAL FORCE BETWEEN SATURN AND RING OBJECT (IN 10,000 N)
100	38
120	26
130	22
150	17
180	12
200	9
220	8
250	6
280	5

5. Use the data in the table to make a graph of the relationship between distance and gravitational force. Label your graph "Gravitational Force vs. Distance."

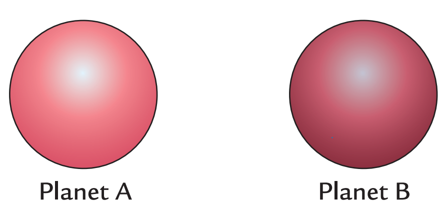
   Note: Put the data for distance on the horizontal axis and the data for gravitational force on the vertical axis.

6. Look at your graphed data, and record in your science notebook any relationships you notice.

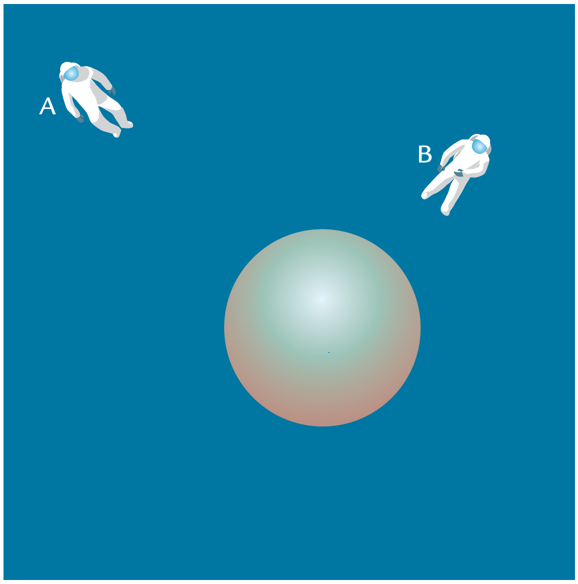
ANALYSIS

1. Compare your two graphs. Identify and explain any
   a. similarities.
   b. differences.

2. Look at the pictures of the two planets below. Their diameters are the same, but Planet B has twice the mass of Planet A. Which one would you expect to have a stronger pull of gravity on its surface? Explain.



3. Look at the picture below of an astronaut at two different distances from a planet. In which position, A or B, would there be a stronger gravitational pull between the astronaut and the planet? Explain.



4. Your friend tells you that if you double the distance of a spacecraft from a planet, the gravitational force is one half as strong. Do you think this is correct? Cite evidence from this activity to support your position.

5. Jupiter is 5.2 times as far from the Sun as Earth is, but the gravitational force between Jupiter and the Sun is stronger than the gravitational force between Earth and the Sun. How can that be?

15 The Effects of Gravity

READING

We experience the effects of gravity every day. On Earth, we feel the pull of gravity every time we try to jump or raise our hands. From earlier activities, you know that the Moon orbits Earth. This is because of the gravitational force between Earth and the Moon. Gravity is also responsible for the orbits of the planets and asteroids in our Solar System.

Astronomers have observed that Earth's star, the Sun, is orbiting the center of the Milky Way Galaxy just like all of the other stars in our Galaxy. A **galaxy** is a collection of stars, and their solar systems, that are gravitationally bound to one another. Each of these observable phenomena can be explained and described by gravity.

The pull of gravity between this astronaut and Earth keeps the astronaut in orbit.

GUIDING QUESTION

How does gravity affect the motions of objects in space?

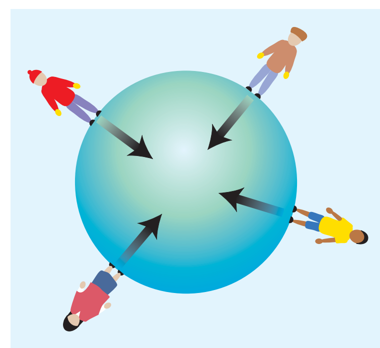
PROCEDURE

1. Follow your teacher's instructions for how to use the Stop to Think questions.
2. Read the text below.

READING

Direction of Gravity

In your everyday life, you are familiar with the gravitational force that pulls things toward the ground. When you drop a ball out of your hand, it falls to the floor. But what direction does the ball go? Many people say the ball falls "down." Look at the diagram at right, which shows people standing on the surface of Earth. "Down" is a different direction at different locations on the surface, but "down" is always the direction toward the center of Earth. Gravity always pulls the center of two objects toward each other.



STOP TO THINK 1

Argentina and Japan are on exactly opposite sides of the Earth. Is "down" in Japan the same direction as "down" in Argentina? Explain.

Strength of Gravity—Mass and Distance

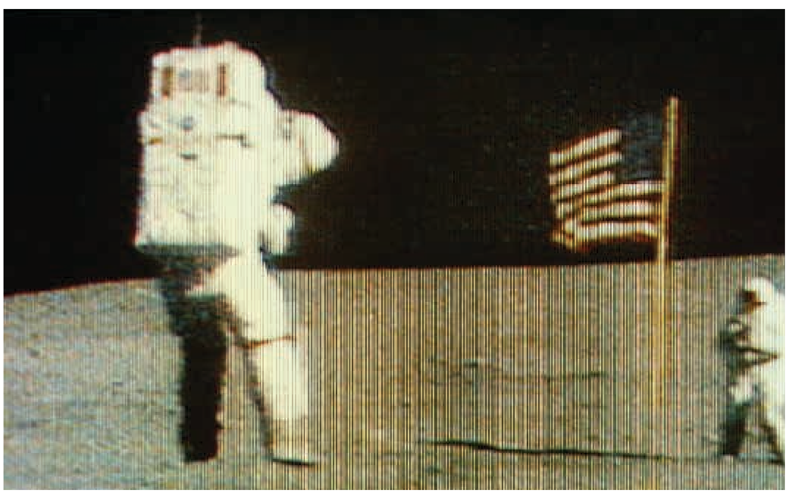
As you learned in the previous activity, the strength of the gravitational force between two objects depends on the mass of the two objects and the distance between them.

All objects, regardless of their mass, exert a gravitational force on all other objects. The more mass an object has, the stronger its gravitational pull. Since Earth is the closest and most massive object near us, its gravitational pull on us is the only gravity we usually notice. The Moon is the next closest space object, but it is less massive. We don't notice the gravitational force between the Moon and us. However, we do observe high and low tides on Earth, which are caused by the gravitational force between the Moon and the water in Earth's oceans.

You may think that gravity only pulls less massive objects toward more massive objects. But the truth is that both objects pull equally on each other. For example, when a ball is thrown into the air, Earth's gravity pulls the ball down toward Earth. The ball's gravity is also pulling Earth up toward the ball. The reason we don't observe Earth moving is because the gravitational force between the ball and Earth isn't strong enough to noticeably move Earth. It is strong enough to noticeably move the ball.

STOP TO THINK 2

When astronauts who are used to gravity on Earth visit the Moon, they can jump much higher on the surface of the Moon. Why is that?



In this television picture from a Moon landing, this astronaut jumped high as he saluted the flag.

Although the gravitational force between two objects decreases as they move farther away from each other, that gravitational force never entirely disappears. There is always a gravitational force between two objects, no matter how far apart they are. The long reach of gravity is important when you are thinking about how far away objects are in a solar system and within a galaxy.

STOP TO THINK 3

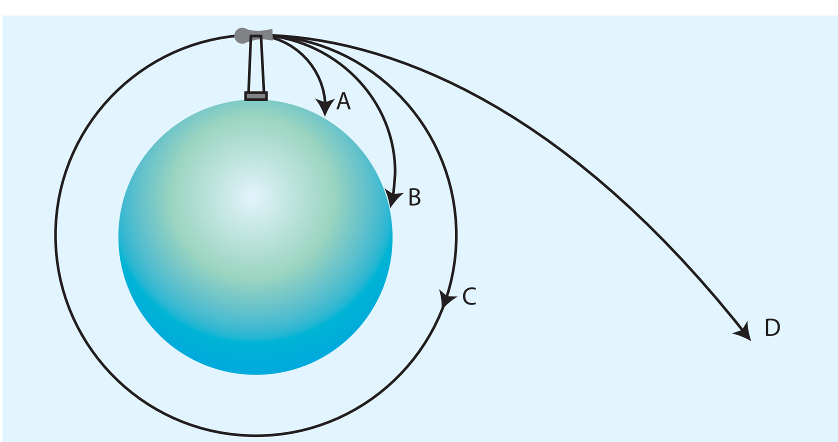
Outside our Solar System, is there any gravitational pull from the Sun?

Across a very long distance, gravity pulled these two galaxies toward each other.

Gravity and Orbiting Objects

Since Earth's gravity pulls everything down toward its center, why don't satellites and even the Moon come crashing down to Earth? Strange as it may seem, gravity helps satellites and the Moon stay in orbit around Earth.

Imagine throwing a ball as fast as you can. It might go 30 m before it hits the ground. The ball curves downward as it travels because the force of gravity is pulling it down. Next, imagine that you have a cannon on the top of a tall tower as in the following diagram. Your cannonball might go quite a distance before it hits the ground (Path A). Now, imagine that you have a cannon that can fire a cannonball faster. It would travel much farther before falling to the ground (Path B). If you could keep firing cannonballs at higher and higher speeds, eventually one would go fast enough that it would "fall" all the way around Earth but never hit the ground (Path C). An orbiting object is being pulled down by gravity, but it is going so fast that it never



A & B: Speed too slow: Cannonball falls back to Earth.

C: Speed just right: Cannonball stays in orbit around Earth.

D: Speed too fast: Cannonball goes beyond orbit and does not return.

actually hits the ground. If a satellite, or even the Moon, were not moving fast enough, it would begin to spiral back to Earth due to the gravitational pull between it and Earth.

Just as the Moon is falling all the way around Earth, the Earth is falling all the way around the Sun. This is what we mean when we say that gravity keeps objects in orbit. Without gravity, there would be no reason for the Earth to orbit any object. Earth would either not move at all or just move through space along a straight path until it hit another object.

Each object in our Solar System orbits the space object that has the greatest gravitational pull on it. So while Earth is sometimes closer to Venus than it is to the Sun, the Sun is so much more massive than Venus. Thus, the gravitational force between the Sun and Earth is greater than the gravitational force between Venus and Earth. This causes Earth to orbit the Sun instead of Venus.

STOP TO THINK 4

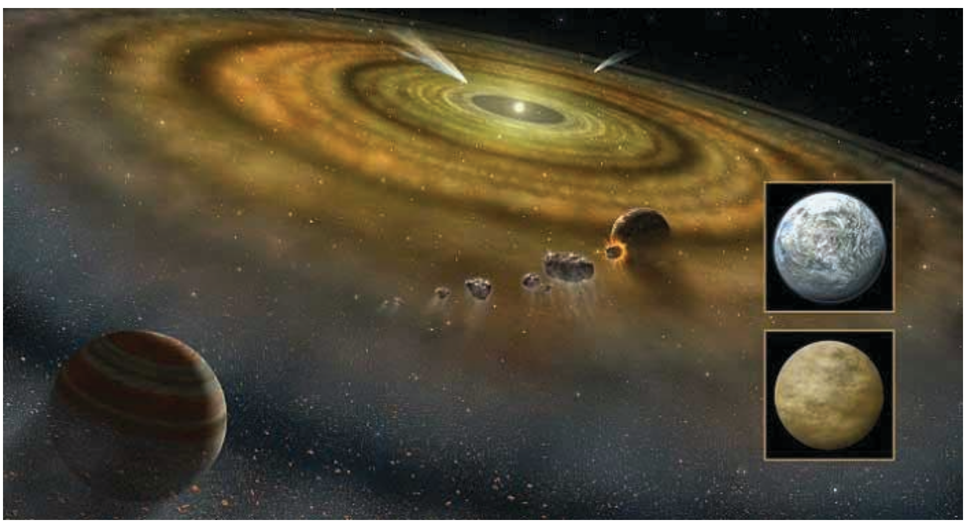
a. What would happen if a satellite orbiting Earth started slowing down?

b. Would our Solar System exist if gravity did not exist? Explain.

A satellite orbiting Earth.

Solar System Formation

We have observed that the motions of space objects within our Solar System occur in consistent, predictable patterns. You might think that the Solar System has been this way forever. But there was a time when our Solar System didn't even exist. Before there were planets, moons, asteroids, comets, or the Sun, there was a huge cloud of gas and dust. At some point around 5 billion years ago, gravity caused two opposite sides of this cloud of gas and dust to come together to make a large spinning disk of gas and dust. Nearly all (99.8%) of the mass in this disk was pulled by gravity into the center to make the Sun. The other 0.2% of the gas and dust left over in the disk began to form planets, moons, asteroids, and comets.



Artist's drawing of the dust and gas surrounding a newly formed solar system.

Asteroids and comets are small in mass and are far enough away from other space objects that gravity never caused them to become part of planets or moons. They are almost exactly the same as they were when the Solar System first formed. This is why astronomers study asteroids and comets to learn more about the history of our Solar System.

The orbits of each of the planets is a result of the initial state of the early Solar System and the gravitational forces between the planets and the Sun. This is why the eight planets in our Solar System all orbit the Sun in the same direction. The gas and dust disk was spinning in this same direction when the Solar System first formed. Other planetary properties, like tilt, are in part due to collisions between objects when the Solar System was still young.

STOP TO THINK 5

Why might astronomers want to use spacecraft to study asteroids?

ANALYSIS

1. Your friend tells you that there is no gravity in space. Based on what you read, do you agree or disagree? Explain.
2. The Hubble Space Telescope pictured on the cover of this book had to be serviced a few times during its mission. After every servicing, the astronauts would push the Hubble Space Telescope a little bit farther away from Earth.
   a. What would change about the gravitational force between Earth and the Hubble Space Telescope after the servicing mission?
   b. The Hubble Space Telescope's orbit is designed so that eventually the telescope will fall into Earth's atmosphere and burn up. Why do you think the servicing missions pushed the spacecraft away from Earth?
3. Draw a picture of what you think the Solar System looked like when it was first forming. Explain how gravity was responsible for what is shown in your picture.

16 Modeling Gravity

COMPUTER SIMULATION

An object's motion in space is determined by the gravitational forces between that object and the other objects in space. Using models, we can investigate how the masses of objects and the distances between them affect the motions of those objects. From these models, we can learn how massive the different objects in our Solar System must be for our Solar System to act the way it does. This knowledge can help us understand the motions of and within galaxies in our universe.

GUIDING QUESTION

How can models help us understand the role of gravity in the motion of space objects?

This photo of a group of galaxies was taken by a camera aboard NASA's Hubble Space Telescope.

MATERIALS

For each pair of students

1 computer with Internet access
1 Student Sheet 13.1, "Planet Information"

For each student

1 Student Sheet 16.1, "Modeling Galactic Gravity"

PROCEDURE

Part A: The Mass of Our Sun

1. Open the Modeling Gravity simulation on your computer.
2. Your teacher will assign you and your partner one of the planets in our Solar System.
3. Find your assigned planet on Student Sheet 13.1, "Planet Information." Identify the distance your assigned planet is from the Sun in astronomical units and how long it takes for your assigned planet to complete one orbit around the Sun—in years.
4. On the computer screen, select your assigned planet.
5. In the upper left corner of the simulation is the simulated distance between your assigned planet and the Sun. Drag your assigned planet until this simulated distance matches the actual planet–Sun distance on Student Sheet 13.1.
6. Use the slider to change the mass of the Sun, and notice that in this simulation, the mass of the Sun changes without changing the distance you set in Step 5. Press "Run Simulation" and observe how long it takes for your assigned planet to complete one orbit.
7. Press "Stop Simulation" and repeat Step 6 until the time it takes for your assigned planet to complete one orbit is the same as what is on Student Sheet 13.1.

   Hint: If you need your planet to orbit faster, increase the gravitational force between the Sun and your planet.
8. Write down the mass of the Sun from Step 7 in your science notebook. Discuss with your partner what you think other groups measured for the mass of the Sun even if they had a different planet.

9. Share your result from Step 8 with a pair who was assigned a different planet, and answer Analysis item 1.

Part B: Galactic Gravity

10. Read the following information about the gravitational forces that determine the motions of objects within galaxies.

In the late 1900s, an astronomer named Vera Rubin was studying the motions of stars in the Andromeda Galaxy. She created a mathematical model based on gravity to predict how fast objects should be orbiting the center of the galaxy. She then observed how fast the objects were actually orbiting. Her data showed that her model's predictions were way off! Since gravity is due to distance and mass, either her mass or distance measurements were wrong. She figured out that there must be mass in the galaxy that cannot be seen. Astronomers call this source of mass dark matter. When Dr. Rubin added dark matter into her model, her new predictions matched her observations. Her model now explained the motion of stars around the center of the Andromeda Galaxy.

Because of Dr. Rubin's discovery, other astronomers have discovered that all galaxies have dark matter, even our own! The gravitational forces from normal matter and dark matter in the Milky Way cause our Solar System to orbit around the center of our Galaxy.

ANALYSIS

1. How many times more massive is the Sun than Jupiter? Use data from this activity and Student Sheet 13.1 to complete your calculation.

2. Follow the instructions on Student Sheet 16.1, "Modeling Galactic Gravity to model a portion of a galaxy. Keep in mind that galaxies usually have billions of stars, but this model only looks at three stars within a galaxy.

3. Think about all you needed to know to complete Student Sheet 16.1.
   a. Describe the role of gravity in determining the
      - orbits of the stars.
      - orbits of the planets around Star A.
      - orbit of the one moon you included in your model.
   b. Do the planets orbiting Star A orbit in the same direction? Explain.

      Hint: Make sure your answer mentions solar system formation.
4. Would it be possible to create a scale model of a galaxy and a solar system on one piece of paper?

   Hint: A typical solar system is about 100 AU from its center to its edge, and the average distance between stars in a galaxy is about 250,000 AU.

17 Choosing a Mission

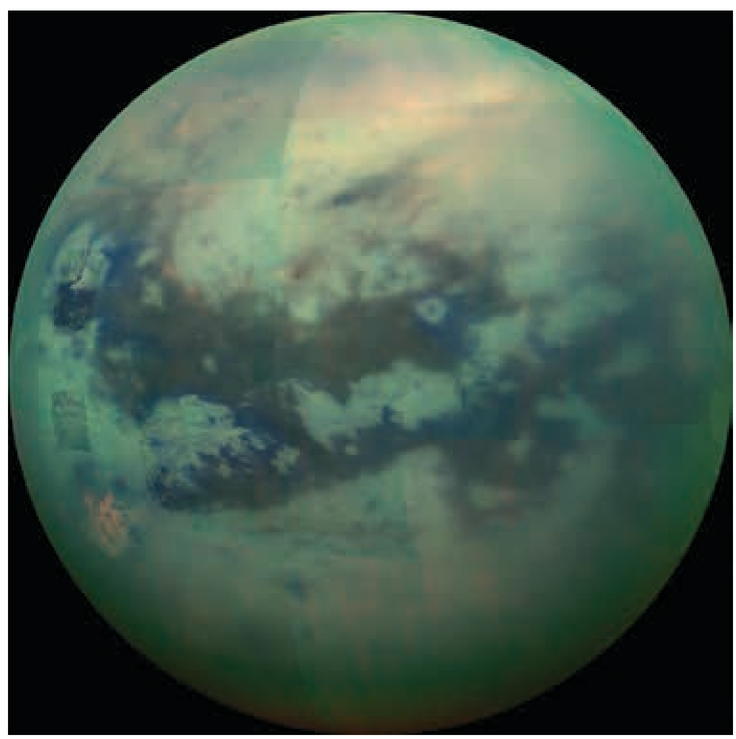
TALKING IT OVER

Millions of dollars are spent on each mission to space. But there is not enough money set aside to fund every project that scientists propose. Now that you know more about what can be learned through space exploration, you are better able to make an informed decision about which future space mission to fund.

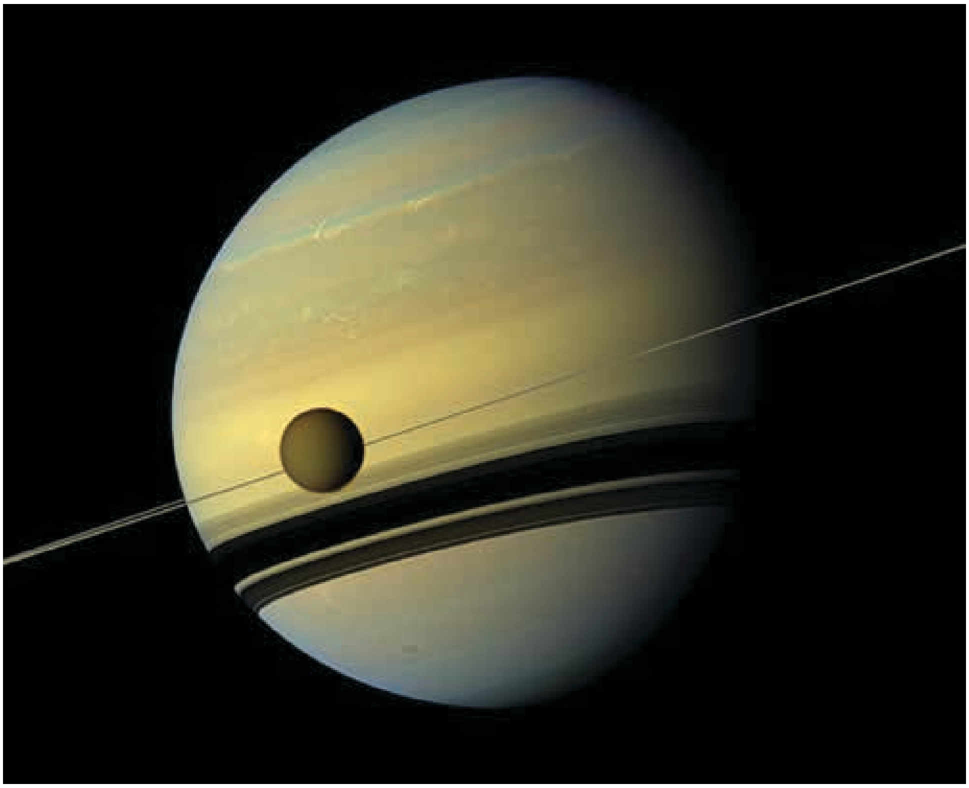
Imagine you have been asked to help decide how NASA should spend this year's budget for space exploration. There is enough money to pay for one space mission. The spacecraft will travel to Titan, one of Saturn's moons.

Titan receives about 1% of the sunlight we receive on Earth. Therefore it has very cold surface temperatures (about –179°C). The Cassini mission, which ended in 2017, learned that even with the cold surface temperatures, there are liquid lakes and seas on Titan's surface! The lakes and seas are made of liquid methane and ethane. The mission also discovered that Titan has an atmosphere like Earth's. It is mostly made of nitrogen. These discoveries made by the Cassini mission have made scientists wonder if life could exist on Titan. The only way we will know for sure is if we collect more data on this mysterious moon.

In this activity, you will get to decide which mission proposal to Titan to fund. The goal is to fund a mission that has potential to benefit society and future space exploration through advancements in technology and scientific understanding.



This image of Titan was captured by the Cassini mission.



This image shows Titan in Saturn's orbit.

GUIDING QUESTION

Which mission to Titan should we fund, and why?

MATERIALS

For each student

1 Student Sheet 17.1, "Comparing Three Space Mission Proposals"

PROCEDURE

1. Read the three proposed space missions to Titan on the following pages. On Student Sheet 17.1, "Comparing Three Space Mission Proposals," record your answers to the following questions:
   - What can scientists learn on the mission?
   - What challenges might the mission face?
   - What are the similarities and differences between the missions?
2. Use the information you recorded on Student Sheet 17.1 and anything else you have learned in this unit to evaluate the mission proposals with your group of four students. Discuss how you think the money should be spent.

3. Compare the mission proposals by completing Student Sheet 17.1. In the last column of the table, rank on a scale of 1 to 3 how much you support each mission proposal, with 1 indicating the most support and 3 indicating the least support.

4. With your group, come to an agreement about which mission proposal should be funded. Support your ideas with evidence about the mission proposals. Be sure to discuss the trade-offs of choosing one mission proposal over another.

   Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain why you disagree.

5. Present your group's recommendation to the class.

Mission Proposal A

The goal of this mission is to collect data to understand the similarities and differences between Titan and Earth. To collect data, scientists will build a spacecraft to orbit Titan. They will also build two science instruments to send to Titan's surface.

The first instrument is an atmospheric balloon. It will gather data about the atmosphere from 10 km above Titan's surface. The balloon can take close-up pictures of the surface.

The second instrument is a lake lander. It will float on one of Titan's lakes. This lander will gather data about the surface liquid and the surface conditions. It will also determine how deep the mysterious bodies of surface liquid on Titan are.

These two instruments will be collecting data that can help scientists learn if there is life on Titan's surface. The instruments would send their data back to the spacecraft to be analyzed. These data will help scientists unlock the mysteries of Titan.

Computer generated illustration of the balloon and the lander on Titan.

Mission Proposal B

The goal of this mission is to use and test a new energy-source technology. It would power the instruments on a spacecraft orbiting and observing Titan. This mission is similar to the Cassini mission. But this mission would use new instruments and updated models of instruments used during the Cassini mission. These instruments would allow scientists to make the most detailed observations of Titan ever made.

The collected data could help scientists plan their next space mission to Titan. Similar data were used to plan the many missions to Mars. The energy-source technology would be tested to see if it can power the spacecraft and its instruments for the length of the mission.

If it is successful, this energy source technology could be used to power spacecraft designed to go well beyond our Solar System. If we ever want to visit another star or solar system in our Galaxy, we must have the right energy-source to do so.

A materials engineer holds up tiny devices that help transform thermal energy into electrical energy.

Mission Proposal C

The goal of this mission is to explore the mysterious seas of Titan. This mission would send a self-driving submarine to Titan's largest sea. This spacecraft would be able to conduct scientific tests and send the data back to scientists on Earth.

Computer generated illustration of a self-driving submarine in a sea on Titan.

Scientists could use the data from the submarine to better understand what chemicals exist in Titan's seas. They could also learn about the depth of the seas and what features are on the seabed. This submarine would allow scientists to explore Titan's mysterious seas in more detail than ever before!

This mission would allow scientists and engineers to develop self-driving technologies that have never been used before. These vehicles could benefit humans in space and on Earth.

ANALYSIS

1. What other information do you wish you had before making a final decision?
2. For the mission proposal you chose, what advancements in technology or engineering do you think this mission could offer?
3. Write a letter to NASA stating your recommendation for which of the three mission proposals to fund. Convince the agency with evidence you gathered in this activity and unit. Be sure to present the trade-offs of your recommendation.

Solar System and Beyond

UNIT SUMMARY

Phases of the Moon

From Earth, we can observe the Moon's appearance changing from day to day. We call these changes *phases.* The Moon's phases repeat in a cycle about every 29 days. Because there is a pattern in which the phases occur, we can predict when certain phases of the Moon will appear. Astronomers figured out that the phases are caused by the Moon's orbit around Earth. Depending on where the Moon is in its orbit, a different portion of the Moon that is lit up by the Sun is visible on Earth. During a new moon phase, no portion of the Moon facing Earth is lit up by the Sun. During a full moon, the entire portion of the Moon lit up by the Sun is facing Earth.

Eclipses

An eclipse occurs when one space object blocks sunlight from reaching another space object. On Earth, we can observe two types of eclipses: solar and lunar. A solar eclipse occurs when the Moon passes between Earth and the Sun such that parts of Earth experience darkness during daytime. A lunar eclipse occurs when the Moon passes into Earth's shadow. A lunar eclipse can only occur during a full moon. Eclipses occur a few times each year, but they do not happen during every orbit of the Moon. That's because the Moon's orbital plane is not aligned with Earth's orbital plane around the Sun.

Earth's Orbit and Seasons

Every year, Earth completes one orbit around the Sun. During this time, the people on Earth experience changes in the amount of daylight hours, how direct the sunlight is, and the seasons. All three of these phenomena occur because Earth's axis is tilted. Earth's tilt causes different parts of Earth to receive different amounts of sunlight depending on where Earth is in its orbit. For example, in June and July, Earth's Northern Hemisphere is tilted toward the Sun, which means that daylight lasts longer and sunlight is more direct because of the Sun's angle. This is why the Northern Hemisphere experiences summer during June and July. The Southern Hemisphere is on the other side of the equator (and thus tilted in the opposite direction). The seasons there are opposite the Northern Hemisphere's, making June and July winter.

The Size and Scale of the Solar System

Our Solar System consists of the Sun, eight planets, their moons, asteroids, comets, and dwarf planets. The planets closest to the Sun are smaller and made of rock, whereas the planets farther away are larger and gaseous. Objects in our Solar System are so far away that it's sometimes hard to imagine the distances. For example, the distance from Earth to Venus is the same as traveling around Earth 950 times!

There are also large differences in the sizes of different space objects in our Solar System. For example, comparing the smallest planet, Mercury, to the largest planet, Jupiter, you could fit 23,000 Mercuries in the amount of space that Jupiter takes up.

To help understand the distances between and sizes of objects in our Solar System, it can be helpful to build scale models.

Gravity's Role in the Solar System and the Galaxy

While it might not feel like we are moving, Earth is constantly orbiting the Sun, just as all planets and objects in our Solar System are. The reason for this is gravity. The Sun is massive. Its gravitational pull on all of the planets, even those at the far reaches of the Solar System, is enough to make those planets orbit the Sun. The reason planets orbit the Sun rather than crashing into it has to do with how the Solar System first formed.

At some point around 5 billion years ago, gravity pulled together two sides of a large cloud of gas and dust. The gas and dust became a spinning disk. Nearly all (99.8%) of the mass in that disk was pulled into the center by gravity to make the Sun. The other 0.2% of the gas and dust in the disk began to form planets, moons, asteroids, and comets.

Our Galaxy, the Milky Way, also depends on gravity as it holds the stars and their solar systems in orbit around its center.

Essential Scientific Terms

cycle

Earth's tilt

galaxy

gravity

model

moon phases

pattern

scale

solar system

APPENDIX

A Science and Engineering

THE NATURE OF SCIENCE AND ENGINEERING

If someone asked you the question, "What is science?" how would you answer?

You might reply that it is knowledge of such subjects as Biology, Chemistry, Earth Science, and Physics. That would be only partly correct. Although science is certainly related to the accumulation and advancement of knowledge, it is much more than that. Science is a way of exploring and understanding the natural world.

According to the American Association for the Advancement of Science (AAAS), two of the most fundamental aspects of science are that the world is understandable and that scientific ideas are subject to change.

Scientists believe that the world is understandable because things happen in consistent patterns that we can eventually understand through careful study. Observations must be made and data collected for us to discover the patterns that exist in the universe. At times scientists have to invent the instruments that allow them to collect this data. Eventually, they develop theories to explain the observations and patterns. The principles on which a theory is based apply throughout the universe.

When new knowledge becomes available, it is sometimes necessary to change theories. This most often means making small adjustments, but on rare occasions it means completely revising a theory. Although scientists can never be 100% certain about a theory, as knowledge about the universe becomes more sophisticated most theories become more refined and more widely accepted. You will see examples of this process as you study the history of scientists' understanding of such topics as elements and the periodic table, the cellular basis of life, genetics, plate tectonics, the solar system, and the universe in this middle school science program.

While the main goal of science is to understand phenomena, the main goal of engineering is to solve problems. Like science, engineering involves both knowledge and a set of practices common across a range of engineering problems. Just as scientists start by asking questions, engineers start by defining problems. Just as scientists search for explanations for phenomena, engineers search for solutions to problems.

Science and engineering often build on each other. For example, scientists use instruments developed by engineers to study the natural world. And engineers use scientific principles when designing solutions to problems.

Scientific Inquiry

Inquiry is at the heart of science, and an important component of inquiry is scientific investigation, including experimentation. Although scientists do not necessarily follow a series of fixed steps when conducting investigations, they share common understandings about the characteristics of a scientifically valid investigation. For example, scientists obtain evidence from observations and measurements. They repeat and confirm observations and ask other scientists to review their results. It is important for scientists to avoid bias in designing, conducting, and reporting their investigations and to have other unbiased scientists duplicate their results. Some types of investigations allow scientists to set up controls and vary just one condition at a time. They formulate and test hypotheses, sometimes collecting data that lead them to develop theories.

When scientists develop theories they are constructing models and explanations of the patterns and relationships they observe in natural phenomena. These explanations must be logically consistent with the evidence they have gathered and with evidence other scientists have gathered. Hypotheses and theories allow scientists to make predictions. If testing turns out to not support a prediction, scientists may have to look at revising the hypothesis or theory on which the prediction was based.

Engineering Design

An engineer uses science and technology to build a product or design a process that solves a problem or makes the world better. Engineering design refers to the process engineers use to design, test, and improve solutions to problems. Like scientists, engineers design investigations to test their ideas, use mathematics, analyze their data, and develop models.

Since most solutions in the real world are not perfect, engineers work to develop the best solutions they can, while balancing such factors as the function, cost, safety, and usability of their solutions. The factors engineers identify as important for solutions to a problem are called criteria and constraints. Most engineering solutions have one or more trade-offs—desired features that must be given up in order to gain other more desirable features.

Science as a Human Endeavor

Science and engineering are human activities. People from all over the world engage in science and engineering and use scientific information and technological solutions. The types of questions a scientist asks and the types of problems an engineer tries to solve are influenced by what they think is important. And what they think is important to investigate often depends on their background, experiences, and perspective. This is why it is essential for all types of people to become scientists and engineers—to be sure science and engineering respond to their interests and needs and to be sure that there are diverse ideas to enrich explanations and arguments. Participation by a wide variety of people in science and engineering will lead to greater and swifter progress toward understanding how the natural world works and solving problems facing individuals, communities, and the environment.

Visit the *SEPUP Third Edition* page for each unit of the SEPUP website at *www.sepuplhs.org/middle/third-edition* to learn more about the interests and accomplishments of diverse scientists and engineers. Each unit highlights examples of people from varied backgrounds in careers that contribute to and depend on the advancement of science and technology.

References

American Association for the Advancement of Science (AAAS). (1990). Project 2061: Science for all Americans. New York: Oxford University Press.

National Research Council. (2012). *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Committee on a Conceptual Framework for New K–12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

APPENDIX

B Science Safety

SCIENCE SAFETY GUIDELINES

YOU ARE RESPONSIBLE for your own safety and for the safety of others. Be sure you understand the following guidelines and follow your teacher's instructions for all laboratory and field activities.

Before the Investigation

- Listen carefully to your teacher's instructions, and follow any steps recommended when preparing for the activity.
- Know the location and proper use of emergency safety equipment, such as the safety eye-and-face wash, fire blanket, and fire extinguisher.
- Know the location of exits and the procedures for an emergency.
- Dress appropriately for lab work. Tie back long hair and avoid wearing dangling or bulky jewelry or clothing. Do not wear open-toed shoes. Avoid wearing synthetic fingernails—they are a fire hazard and can tear protective gloves.
- Tell your teacher if you wear contact lenses, have allergies to latex, food, or other items, or have any medical condition that may affect your ability to perform the lab safely.
- Make sure the worksurface and floor in your work area are clear of books, backpacks, purses, or other unnecessary materials.
- Ask questions if you do not understand the procedure or safety recommendations for an activity.
- Review, understand, and sign the Safety Agreement, and obtain the signature of a parent or guardian.

During the Investigation

- Carefully read and follow the activity procedure and safety recommendations.
- Follow any additional written and spoken instructions provided by your teacher.
- Use only those activities and materials approved by your teacher and needed for the investigation.
- Don't eat, drink, chew gum, or apply cosmetics in the lab area.
- Wear personal protective equipment (chemical splash goggles, lab aprons, and protective gloves) appropriate for the activity.
- Do not wear contact lenses when using chemicals. If your doctor says you must wear them, notify your teacher before conducting any activity that uses chemicals.
- Read all labels on chemicals, and be sure you are using the correct chemical.
- Keep chemical containers closed when not in use.
- Do not touch, taste, or smell any chemical unless you are instructed to do so by your teacher.
- Mix chemicals only as directed.
- Use caution when working with hot plates, hot liquids, electrical equipment, and glassware.
- Follow all directions when working with live organisms or microbial cultures.
- Be mature and cautious, and don't engage in horseplay.
- Report any unsafe situations, accidents, or chemical spills to your teacher immediately.
- If you spill chemicals on your skin, wash it for 15 minutes with large amounts of water. Remove any contaminated clothing and continue to rinse. Ask your teacher if you should take other steps, including seeking medical attention.
- Respect and take care of all equipment.

After the Investigation

- Dispose of all chemical and biological materials as instructed by your teacher.
- Clean up your work area, replace bottle caps securely, and follow any special instructions.
- Return equipment to its proper location.
- Wash your hands with soap and warm water for at least 20 seconds after any laboratory activity, even if you wore protective gloves.

Your teacher will give you an agreement similar to the one below to sign.

Science Safety Agreement

STUDENT

I, _________________________, have read the attached Science Safety Guidelines for students and have discussed them in my classroom. I understand my responsibilities for maintaining safety in the science classroom. I agree to follow these guidelines and any additional rules provided by the school district or my teacher.

Student Signature____

Date_____________________

PARENT OR GUARDIAN

Please review with your student the attached Science Safety Guidelines, which include the safety responsibilities and expectations for all students. It is important that all students follow these guidelines in order to protect themselves, their classmates, and their teachers from accidents. Please contact the school if you have any questions about these guidelines.

I, _________________________, have read the attached guidelines and discussed them with my child. I understand that my student is responsible for following these guidelines and any additional instructions at all times.

Parent or Guardian Signature____

Date_____________________

APPENDIX

C Science Skills

THE FOLLOWING PAGES include instructional sheets that you can use to review important science skills:

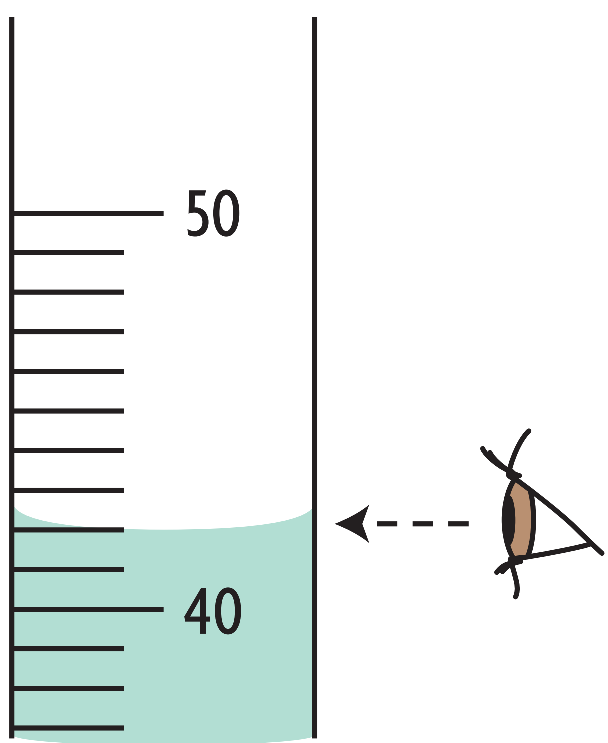
- Reading a Graduated Cylinder
- Using a Dropper Bottle
- Bar Graphing Checklist
- Scatterplot and Line Graphing Checklist
- Interpreting Graphs
- Elements of Good Experimental Design
- Using Microscopes

READING A GRADUATED CYLINDER

A graduated cylinder measures the volume of a liquid, usually in milliliters (mL). To measure correctly with a graduated cylinder:

1. Determine what measurement each unmarked line on the graduated cylinder represents.
2. Set the graduated cylinder on a flat surface and pour in the liquid to be measured.
3. Bring your eyes to the level of the fluid's surface. (You will need to bend down!)
4. Read the graduated cylinder at the lowest point of the liquid's curve (called the *meniscus*).
5. If the curve falls between marks, estimate the volume to the closest milliliter.

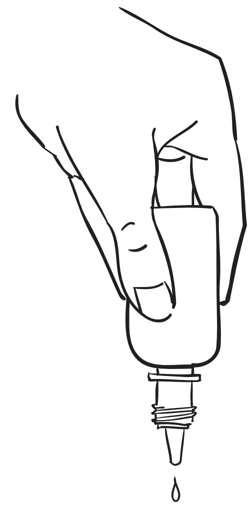
The example below shows a plastic graduated cylinder that contains 42 mL of liquid.



USING A DROPPER BOTTLE

Incorrect

Holding the dropper bottle at an angle creates drops that vary in size.



Correct

Holding the dropper bottle vertically creates drops that are more consistent in size.

BAR GRAPHING CHECKLIST

Sample Graph

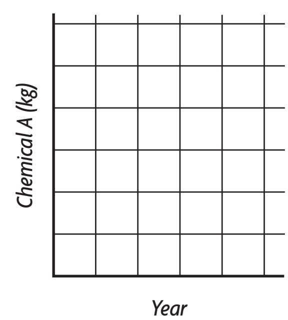
Follow the instructions below to make a sample bar graph.

- [ ] Start with a table of data. This table represents the amount of Chemical A that the Acme Company used each year from 2011 to 2015.

Year	Chemical A used (kg)
2011	100
2012	80
2013	110
2014	90
2015	105

- [ ] Determine whether a bar graph is the best way to represent the data.

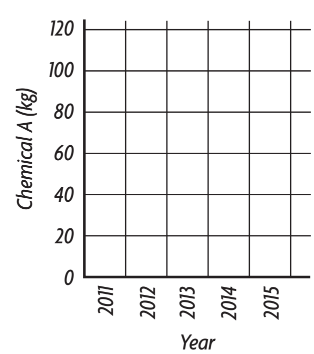
- [ ] If so, draw the axes. Label them with the names and units of the data.



- [ ] Decide on a scale for each axis. Be sure there is enough space for all the data and that it's not too crowded.

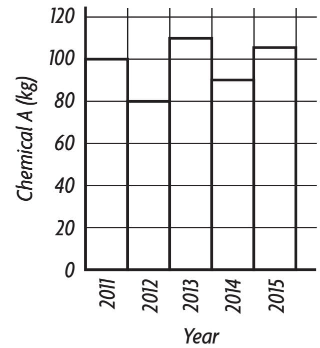
Year axis: 1 block = 1 year
Chemical A axis: 1 block = 20 kilograms

- [ ] Mark intervals on the graph, and label them clearly.

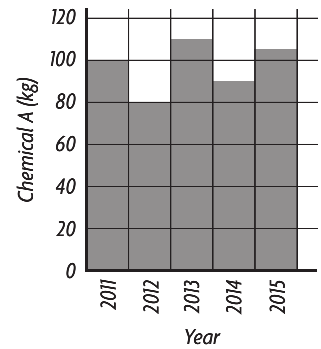


BAR GRAPHING CHECKLIST (continued)

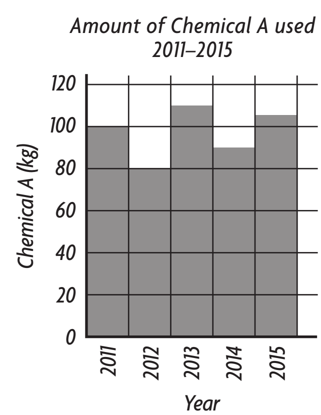
☐ Plot your data on the graph.



☐ Fill in the bars.



☐ Title your graph. The title should describe what the graph shows.



SCATTERPLOT AND LINE GRAPHING CHECKLIST

Sample Graph

Follow the instructions below to make a sample graph.

- [ ] Start with a table of data.

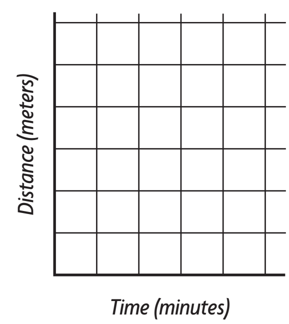
MOTION OF A BALL

Time (minutes)	Distance (meters)
0	0
1	5
2	9
3	16
4	20
5	27

- [ ] Determine whether a line graph or a scatterplot is the best way to represent the data.

LINE GRAPH

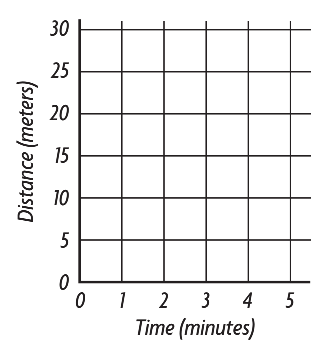
- [ ] Draw the axes. Label them with the names and units of the data.



- [ ] Decide on a scale for each axis. Be sure there is enough space for all the data and that it's not too crowded.

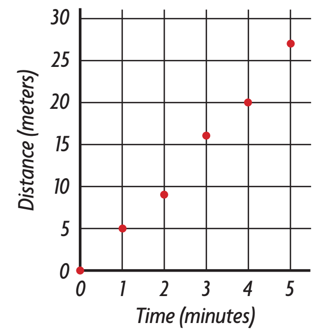
Time axis: *1 block = 1 minute*
Distance axis: *1 block = 5 meters*

- [ ] Draw intervals on the graph, and label them clearly.



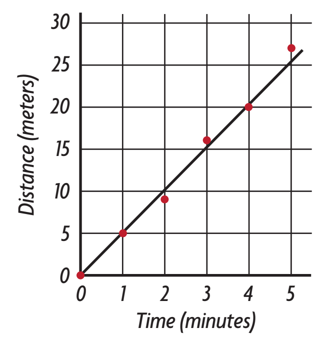
SCATTERPLOT AND LINE GRAPHING CHECKLIST (continued)

☐ Plot your data on the graph.

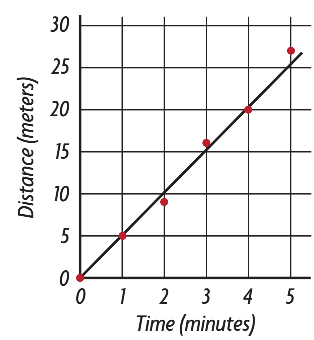


☐ For a scatterplot, leave the points unconnected.

For a line graph, draw a smooth line or curve that follows the pattern indicated by the position of the points.



☐ Title your graph. The title should describe what the graph shows.



☐ If more than one data set has been plotted, include a key.

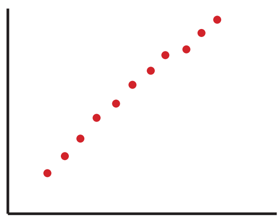
● = *large ball*

○ = *small ball*

INTERPRETING GRAPHS

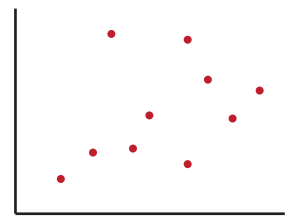
Determine the path that describes the data.

Is there a relationship?



There is a pattern.

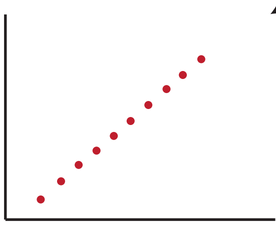
Relationship



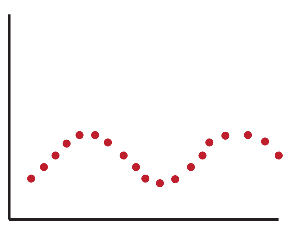
There is no pattern.

No relationship

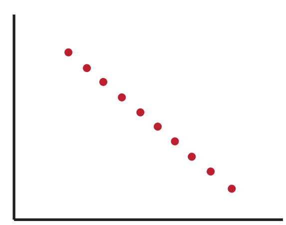
What is the general trend of the data?



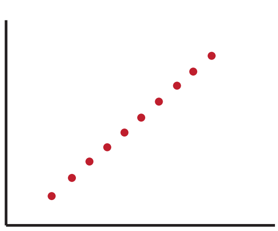
Positive: as x increases, y increases



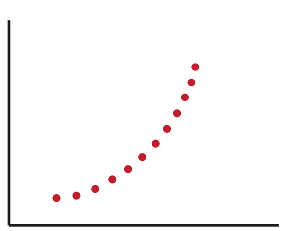
Cyclical: as x increases, y repetitively increases and decreases



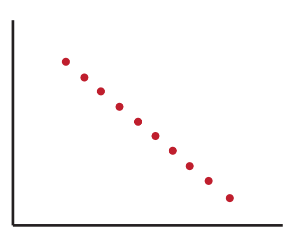
Negative: as x increases, y decreases



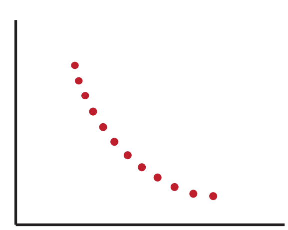
Linear: as x increases, y consistently increases (sometimes called "direct")



Nonlinear: as x increases, y increases at a changing rate



Linear: as x increases, y consistently decreases



Nonlinear: as x increases, y decreases at a changing rate (sometimes called "inverse")

INTERPRETING GRAPHS (continued)

Define the components of the graph.

Things you can say:

"The title of the graph is …"

"The independent variable in this graph is …"

"The dependent variable in this graph is …"

"__________ is measured in ____________________"

Create a description of what the graph reveals.

Things you can say:

"This graph shows that …"

"As the __________ increases, the …"

"The ______ has the highest …"

"__________ is different from ____________ because …"

"The___________ peaked at …"

"The rate of ________ increased from …"

Describe how the graph relates to the topic.

Things you can say:

"This graph is important to understanding _________because …"

"This graph supports the claim that ______________ because …"

"This graph refutes the claim that ______________ because …"

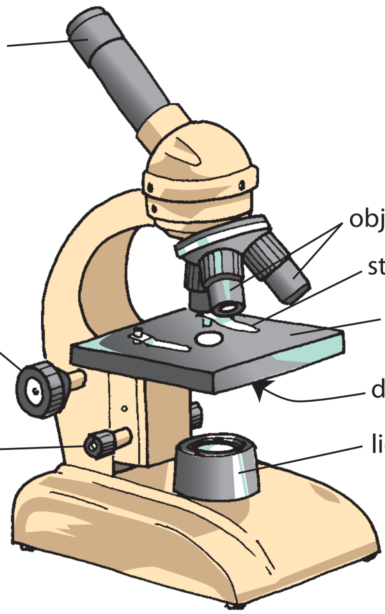
ELEMENTS OF GOOD EXPERIMENTAL DESIGN

An experiment that is well designed

- builds on previous research.
- is based on a question, observation, or hypothesis.
- describes all steps in a procedure clearly and completely.
- includes a control for comparison.
- keeps all variables—except the one being tested—the same.
- describes all data to be collected.
- includes precise measurements and all records of data collected during experiment.
- may require multiple trials.
- can be reproduced by other investigators.
- respects human and animal subjects.

Note: Elements may vary depending on the problem being studied.

USING MICROSCOPES



Focusing a Microscope

Be sure that your microscope is set on the lowest power before placing your slide onto the microscope stage. Place the slide on the microscope stage. Center the slide so that the sample is directly over the light opening, and adjust the microscope settings as necessary. If the microscope has stage clips, secure the slide in position so that it does not move.

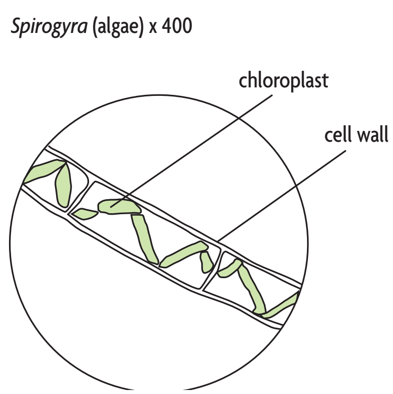
- Observe the sample. Focus first with the coarse-focus knob, and then adjust the fine-focus knob.
- After switching to a higher power magnification, be careful to adjust the focus with the fine-focus knob only.
- Return to low power before removing the slide from the microscope stage.

Safety

Always carry a microscope properly with both hands—one hand underneath and one holding the microscope arm. When you are working with live organisms, be sure to wash your hands thoroughly after you finish the laboratory.

Some Tips for Better Drawings

- Use a sharp pencil and have a good eraser available.
- Try to relax your eyes when looking through the eyepiece. You can cover one eye or learn to look with both eyes open. Try not to squint.
- Look through your microscope at the same time as you do your drawing. Look through the microscope more than you look at your paper.
- Don't draw every small thing on your slide. Just concentrate on one or two of the most common or interesting things.
- You can draw things larger than you actually see them. This helps you show all of the details you see.
- Keep written words outside the circle.
- Use a ruler to draw the lines for your labels. Keep lines parallel—do not cross one line over another.
- Remember to record the level of magnification next to your drawing.



APPENDIX

D The International System of Units

MEASUREMENTS THAT APPEAR in this program are expressed in metric units from the International System of Units, otherwise known as *SI units* (from Système Internationale d'Unités), which was established by international agreement. Virtually all countries in the world mandate use of the metric system exclusively. The United States does not use the metric system for many measurements, although it has been the standard for the scientific community in the United States for more than 200 years. A U.S. government effort to convert from the United States customary system to metric measurements in all realms of life has yet to extend far beyond governmental agencies, the military, and some industries.

The reason that many countries have replaced their traditional measurement systems with the metric system is its ease of use and to improve international trade. There are far fewer units to understand in comparison to the system commonly used in the United States. The metric system has only one base unit for each quantity and larger or smaller units are expressed by adding a prefix. The table below shows the base units in the International System of Units.

QUANTITY	BASE UNIT
Length	meter (m)
Mass	kilogram (kg)
Time	second (s)
Temperature	kelvin (K)
Electric current	ampere (A)
Luminous intensity	candela (cd)
Mole	mole (mol)

Other international units appearing in SEPUP's *Issues and Science* units are shown in the table below:

QUANTITY	UNIT	COMMON EXAMPLE
Temperature	Celsius (°C)	Room temperature is about 20° Celsius
Volume	liter (L)	A large soda bottle contains 2 liters.
Mass	gram (g)	A dollar bill has the mass of about 1 gram.
Wavelength	nanometer (nm)	Visible light is in the range of 400 to 780 nanometers

The International System's prefixes change the magnitude of the units by factors of 1,000. Prefixes indicate which multiple of a thousand is applied. For example, the prefix *kilo-* means 1,000. Therefore, a kilometer is 1,000 meters and a kilogram is 1,000 grams. To convert a quantity from one unit to another in the metric system, the quantity needs only to be multiplied or divided by multiples of 1,000. The chart below shows the prefixes for the metric system in relation to the base units. *Note*: Although it is not a multiple of 1,000 the prefix *centi-* is commonly used, for example, in the unit centimeter. Centi- represents a factor of one 100th.

METRIC PREFIX	FACTOR	FACTOR (NUMERICAL)
giga (G)	one billion	1,000,000,000
mega (M)	one million	1,000,000
kilo (k)	one thousand	1,000
[UNIT]	one	1
milli (m)	one one-thousandth	1/1,000
micro (μ)	one one-millionth	1/1,000,000
nano (n)	one one-billionth	1/1,000,000,000

APPENDIX

E Literacy Strategies

THE FOLLOWING PAGES include instructional sheets and templates for some of the literacy strategies that are used throughout this book. Use them for reference or to copy into your science notebook.

- Oral Presentations
- Reading Scientific Procedures
- Keeping a Science Notebook
- Writing a Formal Investigation Report
- Constructing a Concept Map
- Developing Communication Skills

ORAL PRESENTATIONS

- Your presentation time is short. Focus your presentation on the most important ideas you need to communicate.
- Communicate clearly by planning your words in advance. When speaking, talk slowly and loudly, and look at your audience.
- Group members should ask for and give each other support if they need help expressing a key word or concept.
- Include graphs and maps when possible. Make sure the type or handwriting and the images are large enough for everyone in the audience to see them.
- While you have your own opinions on a topic, it is important that you present unbiased and complete information. Your audience can then make their own conclusions.
- All the members of a group must participate.
- Since any group member may be asked to answer questions from the class, all group members should fully understand the presentation.
- In a group presentation, you could all play the role of different experts when presenting your information. The class would represent the community members who might be making a decision on the issue.

READING SCIENTIFIC PROCEDURES

The purpose of reading a scientific procedure is to find out exactly what to do, when to do it and with what materials, in order to complete all the steps of an investigation.

If you read a step and are not sure what to do, try these strategies:

- Re-read the previous step.
- Re-read the step that confuses you. Sometimes re-reading clarifies the information.
- Ask your partner if he or she understands what the step says to do.
- Ask your partner if there are words you don't understand.
- Ask your partner to explain what the step says to do.
- Ask your partner to read the step aloud as you listen and try to do what your partner is describing.
- Re-read the purpose (Guiding Question) of the investigation.
- Try to say the purpose of the step out loud in your own words.
- Look at the clues in the pictures of the activity.
- Peek at other groups and listen to see if they are doing the step that confuses you.
- Tell your teacher exactly what you are confused about and why it doesn't make sense.

KEEPING A SCIENCE NOTEBOOK

- Write in blue or black ink.
- Cross out mistakes or changes with a single line. Do not erase or use correction fluid.
- Write neatly.
- Record the date of each entry.
- For each new investigation, write down the following:

Title:

Purpose:

Re-write the Guiding Question in your own words.
Hint: What are you going to do? Why are you going to do it?

Materials:

Place a "√" here after you have collected the necessary materials.

Procedure:

Write down whether you understand the procedure.

Data:

Record observations, measurements, and other lab work.
Include data tables, charts, diagrams, and/or graphs when needed.
Be sure to label your work clearly.

- Sometimes, you may want to do the following:

Make inferences or draw conclusions based on the data.

I think my results mean . . .
I think that this happened because . . .

Reflect on how the activity worked in your group.

This is what went well . . This is what did not go well . . .
If I could do this activity again, I would . . .

Think about what questions you still have.

I wonder if . . .
I'm not sure about . . .

Keep track of new vocabulary and ideas.

A key word I learned is . . .
I would like to find out what happens when . . .
One interesting thing to do would be to . . .

KEEPING A SCIENCE NOTEBOOK (continued)

The following is a guide to help you conduct investigations. However, depending on the investigation, you may not always use all of steps below or use them in the same order each time.

Title: Choose a title that describes the investigation.

Purpose: What am I looking for? Write what you are trying to find out in the form of a question.

Background: What do I know about the topic? Write a summary of background information you have on the topic that led to the purpose for the investigation.

Hypothesis: Write a statement about what you predict you will see as data in the experiment to answer the question in the "Purpose" and why you are making that prediction.

Experimental Design: How will you answer the question?

Describe the methods you will use (what you will do) to answer the question.

Use short numbered steps that are easy to follow in the lab.

Make a list of the materials you will use to answer the question.

Outline the variables:

- Independent variable (what is being changed)
- Dependent variable (what is being measured)
- Control (what will be used as baseline comparison)

Data: What did you find?

Record observations and measurements.

Use a data table where appropriate to organize the data.

Don't forget to include proper units and clear labels.

At the end of your investigation, do the following:

Make inferences or draw conclusions about the data:

I think my results mean . . .

I think this happened because . . .

Think about any errors that occurred during the investigation:

What did not go as planned?

What steps were hard to follow while doing the investigation and why?

Think about questions you still have that could lead to new investigations:

I wonder if . . .

I'm not sure about . . .

Keep track of new vocabulary and new ideas that could lead to new investigations

I would like to find out what happens when . . .

One interesting thing to do would be to . . .

Reflect on how the activity worked in your group

This is what went well . . . This is what did not go well . . .

If I could do this investigation again, I would . . .

WRITING A FORMAL INVESTIGATION REPORT

Use the information from your science notebook to write a formal report on the investigation you performed.

Title:

Choose a title that describes the investigation.

Abstract: What were you looking for in this investigation, and what did you find?

Write a paragraph that summarizes what you already knew about the topic, your purpose, your hypothesis, and your results and conclusions.

Experimental Design:

Describe the materials and investigational methods you used to answer the question.

State what variables you worked with and any controls.

Data: What did you find?

Report observations and measurements. Include an organized data table if appropriate to help someone reviewing your report to easily see the results.

Don't forget to use proper units of measurement and write clear labels for your table columns.

Data Analysis: Represent the data in a way that can be easily interpreted.

Use graphs, diagrams, or charts where appropriate to help a reviewer interpret your data.

Conclusion: What do the data mean?

Summarize the data.

Discuss your conclusion based on the accuracy of your hypothesis and the data you collected.

Discuss any errors that occurred that may have interfered with the results.

Describe any changes that need to be made the next time the investigation is performed.

Describe any new questions to be investigated based on the results of this investigation.

CONSTRUCTING A CONCEPT MAP

1. Work with your group to create a list of 15–20 words related to the topic.
2. If you are uncertain of the meaning of a word, look it up in the book or your notes or discuss it with your group.
3. Discuss with your group how all of the words on your list are related, and sort your list of words into three to five categories based on these relationships.

   Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain to the rest of the group why you disagree.
4. Identify words that can be used to describe each category.
5. Work with your group to create a concept map on this topic. Follow these steps:

   a. Write the topic in the center of your paper, and circle it.

   b. Place the words describing each category around the topic. Circle each word.

   c. Draw a line between the topic and each category. On each line, explain the relationship between the topic and the category.

   d. Repeat Steps 5b and 5c as you continue to add all of the words on your list to your concept map.

   e. Add lines to connect other related words. Explain the relationship between the words on the line.
6. View the concept maps of other groups. As you look at their concept maps, observe similarities and differences between their maps and yours. Discuss your observations with your group members.

DEVELOPING COMMUNICATION SKILLS

COMMUNICATION	SENTENCE STARTERS
To better understand	One point that was not clear to me was . . . Are you saying that . . . Can you please clarify . . .
To share an idea	Another idea is to . . . What if we tried . . . I have an idea. We could try . . .
To disagree	I see your point, but what about . . . Another way of looking at it is . . . I'm still not convinced that . . .
To challenge	How did you reach the conclusion that . . . What makes you think that . . . How does it explain . . .
To look for feedback	What would help me improve . . . Does it make sense, what I said about . . .
To provide positive feedback	One strength of your idea is . . . Your idea is good because . . . I have an idea. We coud try . . .
To provide constructive feedback	The argument would be stronger if . . . Another way to do it would be . . . What if you said it like this . . .
To discuss information presented in text and graphics	I'm not sure I completely understand this, but I think it may mean . . . I know something about this from . . . A question I have about this is . . . If we look at the graphic, it shows . . .

APPENDIX

F Media Literacy

IMAGINE YOURSELF READING a magazine. A feature article summarizes recent studies on the effectiveness of vitamin supplements and concludes that taking vitamin pills and liquids is a waste of money. A few pages later, an advertisement from a vitamin company claims that one of its products will protect you from all sorts of diseases. Such wide differences in claims that you will see in the popular media are common, but how can you tell which one is correct? "Media literacy" is the term that encompasses the skills we need to develop to effectively analyze and evaluate the barrage of information we encounter every day. Media literacy also includes the ability to use various media to create and communicate our own messages.

A strong background in the process of science helps you build two important skills of media literacy: being able to identify valid and adequate evidence behind a claim and evaluating if the claim is a logical conclusion based on the evidence. The skills share much in common with the process of scientific inquiry, in which you learn to seek out information, assess the information, and come to a conclusion based on your findings.

EVALUATING MEDIA MESSAGES

A "media message" is an electronic, digital, print, audible, or artistic visual message created to transmit information. Media messages can include newspaper articles, political advertisements, speeches, artwork, or even billboards. The following are some of the kinds of questions you might ask as you learn to critically analyze and evaluate messages from various kinds of media. On the next page are three examples of media messages, all related to a common theme. Use these three examples to analyze and evaluate the messages.

1. **Who created this message?**
   Is this person an expert in the content of the message? What credentials does this person have that would make them an expert in this topic? Does this person have any conflicts of interest that may make him or her biased in any way? Who sponsored (or paid for) the message? Does the source of funding have any conflicts of interest?

2. **What creative techniques in the message attract a person's attention?**
   Are there any sensational or emotional words, images, or sounds that grab the viewer's attention? Do any of these words, images, or sounds try to stir up emotions and influence the viewer's ideas?

3. **Does the message cite or mention appropriate sources of factual information?**
   Does the author cite first-person sources when reporting facts? Are the author's sources from credible organizations?

4. **Does the presented evidence completely support the claim?**
   Might there be other information that could support or discredit the message? Does the author make logical inferences and conclusions from the evidence presented in the article?

5. **Who is the target audience of this message?**
   How is this message directed at this particular audience?

6. **Is the message promoting certain values, lifestyles, positions, or ideas either directly or indirectly?**
   Are there any positions or ideas that are being promoted that are not explicit in the message?

EVALUATING INTERNET SOURCES

Imagine that you want to search the Internet to find out about the effectiveness of vitamin supplements so that you can come to your own conclusion. When you are searching for information online, a search engine is searching from over one trillion websites.[1] Determining which websites and sources of information are reliable and which are biased is difficult. To make an informed decision about this topic, you will need to identify accurate and unbiased websites. Below is a suggested list of questions that will help you determine if a particular website is an accurate and unbiased source of information.

1. **Are the authors' names, contact information, and credentials clearly labeled on the website?**
   Accurate websites will usually contain information from knowledgeable authors who have their names, credentials, and contact information clearly labeled on the website. Some websites are managed by a collection of people or an organization, and information on the exact author may not be clearly stated. However,

1. Alpert, Jesse & Hajaj, Nissan. (July 25, 2008). We knew the Web was big. . . . *The Official Google Blog*. Retrieved August 2010 from http://googleblog.blogspot.om /2008/07/we-knew-web-was-big.html.

these organizations should state the names, contact information, and credentials somewhere on their website of the people who represent the organization.

2. **Is the information and the website up to date?**
   Some information that you may be seeking needs to be current. For example, if you were looking for the number of cars in the United States, you would want the most recent data. A study conducted in 1982 would not be helpful in this case. When seeking information that needs to be current, determine if the date the article or information was written is clearly indicated on the website so you can be sure you are accessing the most recent information. Credible websites will usually indicate the date the article or information was created or last updated. Also, the person or organization maintaining the website should be regularly updating the website, so that the majority of links to other websites work.

3. **Are sources of information clearly cited?**
   When factual information is stated in a website, is the source clearly cited so you can refer back to it?

4. **Are there links to more resources on this topic?**
   Authoritative websites will often provide links to further information from other sources that support their claim. Authors of websites that contain information that is biased or inaccurate usually do not provide additional information that supports their claims.

5. **What are other people saying about the author or the organization that produced this information?**
   If you come across information from an author or organization that you are unfamiliar with, perform a search for other information about the author or organization. What are experts writing about the author's or organization's other work?

6. **Why is this website on the Internet?**
   Was this information put on the Internet to inform or to persuade people? Is the author selling something? What is the author's motivation for providing this information?

Further Resources

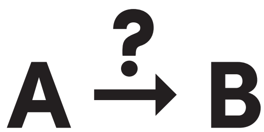
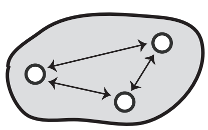
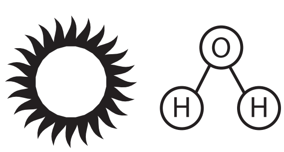
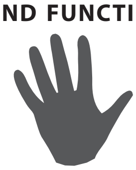
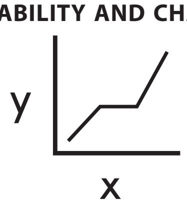
Thier, M., & Daviss, B. (2002). The new science literacy. Portsmouth, NH: Heinemann.

Center for Media Literacy. http://www.medialit.org.

PBS Teachers. Media literacy. http://www.pbs.org/teachers/media_lit.

APPENDIX

G Crosscutting Concepts

PATTERNS 	A pattern is a set of repeating things or events. Scientists observe patterns in their data. Patterns lead to questions about relationships and ideas about what causes these relationships.
CAUSE AND EFFECT 	Events have causes. If "A" causes "B" to happen, they have a cause-and-effect relationship. A major activity of science is to explain how this happens. Sometimes the causes are simple and sometimes they are complex. Sometimes both A and B occur, but one does not cause the other.
SCALE, PROPORTION, AND QUANTITY	Scientific phenomena occur at various scales of size, time, and energy. Phenomena observed at one scale may not be observable at another scale. Scientists use proportional relationships to compare measurements of objects and events. They often use mathematical expressions and equations to represent these relationships.
SYSTEMS AND SYSTEM MODELS 	A system is a group of interacting objects or processes. Describing a system, including its components, interactions and boundaries, and making models of that system helps scientists and engineers understand phenomena and test ideas.
ENERGY AND MATTER 	Tracking changes of energy and matter into, out of, and within systems helps scientists understand the systems' possibilities and limitations. Many cause and effect relationships result from changes of energy and matter.
STRUCTURE AND FUNCTION 	The structure (shape, composition, construction) of an object or living thing determines many of its properties and functions (what the structure can do).
STABILITY AND CHANGE 	For natural and built systems alike, conditions are sometimes stable (the same or within a range), and sometimes they change. Scientists study what conditions lead to either stability or change.

Glossary

astronomer A scientist who studies objects and events beyond Earth's atmosphere, such as the movement of stars and planets.

astronomical unit (**au**) the mean, or average, distance between Earth and the Sun (149,597,870,700 m).

atmosphere The mixture of gases ("air") that surrounds a planet.

benefit An advantage, profit, or gain.

boundaries The extent of a system, separating those components and processes that are part of the system from those that are not. *See* components and system.

components The substances, materials, and processes that make up a system. *See* system.

cycle A sequence of events that repeats.

data Information gathered from an experiment or observations.

Earth's axis The imaginary line around which an object spins, or rotates. Earth rotates around an axis that runs straight through Earth from the North Pole to the South Pole.

Earth's tilt The angle of Earth's axis (approximately 23.5 degrees from perpendicular) relative to Earth's orbital plane around the Sun.

energy The ability to cause objects to change, move, or work.

energy transfer The movement of energy from one object to another.

energy transformation The change of energy from one type to another, such as from chemical to thermal energy.

error Variation between a measurement and the true value of a quantity.

evidence Information that supports or refutes a claim.

force A push or a pull.

galaxy A collection of stars and their solar systems that are gravitationally bound to one another.

gram (**g**) A unit of mass in the metric system; 1 gram is equal to 1,000 milligrams.

gravitational force The amount of gravitational pull between two objects. *See* gravity.

gravity A natural phenomenon that causes objects to be attracted to each other based on each object's mass and the distance between them.

interactions The relationships between the components in a system. *See* components and system.

lunar eclipse When the Moon passes into Earth's shadow.

mass The amount of matter in an object.

matter The stuff that makes up all living and nonliving objects.

meter (m) A unit of length in the metric system; 1 meter is equal to 100 centimeters or 1,000 millimeters.

metric system The worldwide measuring system used by scientists. Also known as the International System of Units (SI).

model Any representation of a system (or its components) used to help one understand and communicate how it works.

moon phases The different shapes of the Moon visible from Earth.

newton (**N**) A unit of force in the metric system, equal to 1 kg•m/s^2.

observation Any description or measurement gathered by the senses or instruments.

orbit A curved path that a space object takes around a star, planet, or moon.

orbital plane A flat two-dimensional plane where a space object is at any point in its orbit.

pattern Something that happens in a repeated and predictable way.

scale The ratio of the size of a real object to the size of a model, map, diagram, or other representation of that object. Can also be used to refer to the general size of objects being referred to, for example molecular scale.

science The systematic study of the natural world.

scientific model *See* model.

scientist Someone who pursues understanding of the natural world by using evidence to answer questions.

SI units The International System of Units (from Système Internationale d'Unités) established by international agreement. SI units are widely used in science, industry, and medicine.

solar eclipse When the Moon passes between Earth and the Sun such that the Moon's shadow causes some places on Earth to experience darkness during daytime.

solar energy Energy that comes from the sun.

solar system A star and all of the objects that orbit it.

spacecraft Rockets, satellites, probes, space stations, and space shuttles that carry various tools and equipment to gather data about space and space objects.

system A group of interacting objects or processes. Every system includes components, interactions, and boundaries. *See* boundaries, components, and interactions.

technology Any product or process made by engineers and scientists.

trade-off A desirable outcome given up to gain another desirable outcome.

Index

Bold page number indicates a definition. *Italic* page number indicates an illustration.

T

U

V

W

Y

Credits

Abbreviations: t (top), m (middle), b (bottom), l (left), r (right), c (center)

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