Chapter 4

Astronomy

Lesson 1
What Makes Up the Solar System?

- How have models of the solar system changed?
- What are planets like?
- What objects besides planets are in the solar system?
- How do objects in the solar system affect Earth?

Lesson 2
What Is Known About Stars?

- How does the sun compare with other stars?
- How do scientists measure distances in space?
- What are the properties of stars?
- What are constellations and galaxies?

Lesson 3
How Do Scientists Study Planets and Stars?

- How do scientists use spectrosopes to analyze light?
- How do telescopes work?
- How are images from telescopes recorded?
- Why do scientists use telescopes in space?

Inquiring about Astronomy

Copy the chapter graphic organizer onto your own paper. This organizer shows you what the whole chapter is all about. As you read the lessons and do the activities, look for answers to the questions and write them on your organizer.
Making a Model of the Solar System

**Explore**

1. Use the data in the table to help you make models of the planets. Find the diameter of each planet. Then find the size to make each planet model.

2. Make a model of each planet from the posterboard. Measure each planet with a metric ruler to make sure it has the correct diameter. Cut out the planets and color them. Record the color you use for each planet.

3. Arrange the models in the order shown on the chart. Mercury is closest to the sun. Remember, this model helps you compare sizes, not distance. The distances are very great.

**Reflect**

Hold the Earth model next to the Venus model, then next to the Jupiter model. Describe how Earth compares in size to Venus and Jupiter.

**Inquire Further**

How many Earth models could be lined up along the diameter of the Jupiter model? Develop a plan to answer this or other questions you may have.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Diameter</th>
<th>Diameter of model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>4,900 km</td>
<td>5 mm</td>
</tr>
<tr>
<td>Venus</td>
<td>12,100 km</td>
<td>12 mm</td>
</tr>
<tr>
<td>Earth</td>
<td>12,800 km</td>
<td>13 mm</td>
</tr>
<tr>
<td>Mars</td>
<td>6,800 km</td>
<td>7 mm</td>
</tr>
<tr>
<td>Jupiter</td>
<td>143,000 km</td>
<td>143 mm</td>
</tr>
<tr>
<td>Saturn</td>
<td>120,500 km</td>
<td>121 mm</td>
</tr>
<tr>
<td>Uranus</td>
<td>51,100 km</td>
<td>51 mm</td>
</tr>
<tr>
<td>Neptune</td>
<td>49,500 km</td>
<td>50 mm</td>
</tr>
<tr>
<td>Pluto</td>
<td>2,300 km</td>
<td>2 mm</td>
</tr>
</tbody>
</table>

(1 mm = approximately 1,000 km)
Exploring Place Value Through Millions

How great a distance do you think you can see? A kilometer? Two kilometers? You can see the sun, can’t you? Would you be surprised to know that the sun is 149,597,900 kilometers from Earth!

A place value chart shows the value of each digit in this number. Each group of three digits—millions, thousands, and ones—is a period.

<table>
<thead>
<tr>
<th>Millions Period</th>
<th>Thousands Period</th>
<th>Ones Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>hundreds</td>
<td>tens</td>
<td>ones</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

This number can be written in several ways:

**Standard Form**
149,597,900

**Expanded Form**
100,000,000 + 40,000,000 + 9,000,000 + 500,000 + 90,000 + 7,000 + 900

**Word Form**
one hundred forty nine million, five hundred ninety seven thousand, nine hundred

Write each number in the two other ways.

1. 3,406,237
2. 60,000,000 + 100,000 + 8,000 + 10 + 5
3. four hundred sixty million, two hundred six thousand, six hundred two

**Talk About It!**

What pattern can you find in the place names in each period?
Lesson 1

What Makes Up the Solar System?

The sun sets, the sky grows dark, and the moon rises. One or two very bright points of light shine among the stars. **WOW!** Maybe they’re planets, like Earth. Earth goes around the sun, and the moon goes around Earth.

**Solar System Models**

As people long ago watched the night sky over many months, certain bright objects seemed to move from one group of stars to another. Because they seemed to wander through the stars, people called these objects wanderers. Today we call them **planets**, from the Greek word meaning “to wander.” Earth is one of nine planets that travel in **elliptical**, or oval, paths around the sun. The sun is a star at the center of this group of planets. Earth and some of the other planets have moons that revolve, or move around them. The sun, the planets and their moons, and other objects that revolve around the sun make up the solar system.

As people observed the sun, moon, planets, and stars, they made models to represent how they thought these objects were related to one another. A **model** shows how something looks or works. Early solar system models showed Earth as the center of everything that exists. It was thought to be the center of the whole universe. Look at the models on the next page to see how ideas about the solar system have changed over time.
△ Ptolemy’s Model

Ptolemy, who lived in Greece in the A.D. 100s, believed that the sun and other objects in the sky revolved around Earth. Find Earth in his model.

△ Copernicus’s Model

In 1543, almost 1,400 years after Ptolemy, the Polish astronomer Copernicus published a new model. He suggested that the sun was at the center of the solar system, with planets revolving in circles around it. Locate the sun and the planets in Copernicus’s model.

△ Modern Solar System Model

Over time, better tools allowed scientists to observe the solar system more exactly. In the early 1600s, Johannes Kepler, a German astronomer, made a model showing the planets traveling in elliptical paths instead of circular paths around the sun. The model that scientists use today is based on Kepler’s model.
The Planets

On Earth, long distances can be measured in kilometers or miles. But in our solar system, the distances between objects are too large to use these units of measure conveniently. Astronomers measure distances in the solar system in astronomical units, or AU. One AU is the average distance from the sun to Earth, about 150,000,000 kilometers. The chart on these two pages tells about planets, including their distances from the sun in AU.

<table>
<thead>
<tr>
<th></th>
<th>Mercury</th>
<th>Venus</th>
<th>Earth</th>
<th>Mars</th>
</tr>
</thead>
</table>
| Average Distance from Sun | 0.39 AU  
57,900,000 km                  | 0.72 AU  
108,200,000 km                 | 1 AU  
150,000,000 km                 | 1.5 AU  
227,900,000 km                 |
| Moons | None                          | None                          | 1                           | 2                           |
| Special Features | Moonlike surface; second-smallest planet | Brightest object in evening or morning sky (other than the moon); surface covered with clouds of sulfuric acid | Only planet known to have living things; has lands, seas, and an oxygen-rich atmosphere | Reddish-brown “deserts” and dark blue-gray or greenish “seas” with no water |
What keeps the planets in their paths, or orbits, as they revolve around the sun? In the late 1600s, Sir Isaac Newton reasoned that the same force that pulls an apple to Earth when it falls from a tree could hold the planets in their orbits. He called this force gravity.

The planets are much closer to Earth than any star except the sun. Because they are so close, they often look brighter than stars. However, planets do not glow from their own heat, the way the sun and other stars do. Planets shine the way the moon does, by reflecting light from the sun.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance from Sun (AU)</th>
<th>Distance from Sun (km)</th>
<th>Known for / Discovery</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jupiter</td>
<td>5.2 AU</td>
<td>778,300,000 km</td>
<td>Known in ancient times; Galileo discovered four moons by telescope in 1610; photos by Voyager spacecraft, 1979</td>
<td>The largest planet; made of gases (a &quot;gas giant&quot;); covered by colored bands of thick clouds; has a stormy area; the Great Red Spot; has one thin ring</td>
</tr>
<tr>
<td>Saturn</td>
<td>9.5 AU</td>
<td>1,427,000,000 km</td>
<td>Known in ancient times; photos by Voyager spacecraft, 1980–1981</td>
<td>Second-largest planet; a &quot;gas giant&quot; with six major rings and hundreds of thousands of ringlets; has yellowish surface covered with liquid hydrogen</td>
</tr>
<tr>
<td>Uranus</td>
<td>19.2 AU</td>
<td>2,869,600,000 km</td>
<td>Discovered in 1781 by William Herschel; photos by Voyager 2, 1986</td>
<td>Made of gases; smaller than Jupiter and Saturn; has eleven narrow rings; appears blue-green</td>
</tr>
<tr>
<td>Neptune</td>
<td>30 AU</td>
<td>4,496,600,000 km</td>
<td>Existence predicted in 1845; discovered by telescope in 1846; photos by Voyager 2 in 1989</td>
<td>Made of gases; has a great dark spot (a spiral storm); looks blue-green; has four complete rings, several incomplete rings</td>
</tr>
<tr>
<td>Pluto</td>
<td>39.4 AU</td>
<td>5,900,100,000 km</td>
<td>Discovered by Clyde W. Tombaugh in 1930</td>
<td>Smallest planet—smaller than Earth's moon; has single moon, Charon, more than half the size of the planet</td>
</tr>
</tbody>
</table>
Other Objects in the Solar System

The moon is nearer to Earth than any other object in the solar system. It revolves around Earth at a distance of about 384,500 kilometers. The moon’s diameter is about a quarter of the diameter of Earth. It is almost as big as Mercury and is bigger than Pluto, the smallest planet. The moon shines by reflecting light from the sun. It seems to change shape depending on how much of the lighted side is facing Earth.

The moon and the planets are not the only objects that orbit the sun. An asteroid is like a small planet. The largest asteroids are about 1,000 kilometers in diameter, about the size of the moons of some planets. Others are less than a kilometer across. Asteroids like the one in the picture orbit the sun in an area called the asteroid belt, which is located between the orbits of Mars and Jupiter.

A meteoroid is a small piece of rock or metal that revolves around the sun. The smallest meteoroids are about the size of a grain of sand. The largest may be 100 meters in diameter, about the length of a football field. Meteoroids form when asteroids collide or comets break up.

Sometimes a meteoroid passes through Earth’s atmosphere. Friction from air particles rubbing against its surface make it so hot that the rock burns. The streak of light caused by the burning rock is a meteor. Meteors are sometimes called “shooting stars.” Find the meteor streaking across the sky among the stars in the picture.

A comet’s head is a huge ball of gases and dust. The frozen center is a few kilometers in diameter. It is surrounded by a cloud of gas and dust, up to 1,000,000 kilometers in diameter.
A comet is a ball of ice, dust, and gases that revolves around the sun in a long, narrow path. A comet can be seen because the gas and dust particles in it reflect light from the sun. Some comets are seen from Earth only once. Then they disappear forever. Others return near Earth regularly. Find the parts of a comet in the picture below.

A comet's tail forms when it gets near the sun. It may be more than 100,000,000 kilometers long. The tail streams out away from the sun.

Some comets pass near the sun in their long, elliptical orbits. Comet Halley reappears in Earth's part of the solar system every 76 years.

Glossary

comet (kom'it), a ball of ice, dust, and gases that travels through space and orbits the sun.
How Objects in the Solar System Affect Earth

The sun is an average-sized star, located at the center of the solar system. Energy from the sun provides the heat and light that is needed for all life on Earth, including the crops in the picture. Without energy from the sun, Earth would be a frozen ball of ice. Like other stars, the sun is a glowing ball of hot gas. It seems much bigger, brighter, and hotter than other stars because it is so much closer to Earth. You will learn more about the sun in the next lesson.

The sun affects Earth without touching it. Unlike the sun, some objects from the solar system actually reach Earth’s surface. Most objects from space that enter Earth’s atmosphere burn up completely. However, if they are very large, like asteroids, they may not burn up completely. A piece of rock and metal that lands on Earth, such as the one shown below, is called a meteorite. Most meteorites came from the asteroid belt, but a few seem to be made of rock from the moon or Mars. Large meteorites can hit the ground with such force that they make craters like the one in the picture. About every million years, a very large meteorite probably hits Earth and makes a huge crater. Look at the picture below to see what a small meteorite can do.

- All living things depend on the sun for light and warmth. The green leaves of plants change sunlight into sugar and give off the oxygen almost all organisms need.

- A 300,000-ton meteorite crashed to Earth almost 50,000 years ago. It formed Meteor Crater, which is in Arizona. The crater is 175 meters deep and 1,275 meters across.

- This car was damaged when a meteorite hit it.

- Small pieces of rock or metal are all that remain of most meteorites that reach Earth. About 500 meteorites hit Earth each year.
The moon and sun also affect Earth by causing the rise and fall of the tides. The diagram shows that the moon’s gravity pulls ocean water toward the moon. The water piles up in a bulge on the side of Earth facing the moon. The water also bulges out on the opposite side of Earth. This is caused by the way forces pull on the water as the moon and Earth move through space. Low tides are in the area between the two bulges.

When the sun and moon are lined up with Earth, their pulls combine and cause very high tides. When they pull at right angles, the tidal bulges are flatter, or lower, than usual.

**Lesson 1 Review**

1. Compare three models of the solar system.
2. What are the planets like?
3. List three objects besides planets that are found in the solar system.
4. List three ways the sun affects Earth.
5. **Place Value Through Millions**
   An AU is 150,000,000 kilometers. Write the number in expanded form and in words.
Lesson 2

What Is Known About Stars?

You will learn:
- how the sun compares with other stars.
- how scientists measure distances in space.
- about the properties of stars.
- what constellations and galaxies are.

From a dark sky, stars twinkle above you. If you looked through a telescope, you might see that the stars are not all the same color. Some are white, some are blue, some are yellow, and some are red. What makes them look like that?

The Sun

You know that the sun is a star at the center of the solar system. Even though it looks much brighter than the other stars, the sun's brightness is just average. Some stars give off more light than the sun, others give off less. The sun looks brighter because it is so much closer to Earth than any other star is.

Like the other stars, the sun is a hot ball of glowing gases. Deep inside the sun, atoms combine in nuclear reactions. These nuclear reactions change small amounts of matter into gigantic amounts of heat and light energy. The huge amounts of energy the reactions give off are what make the sun and all the other stars so hot that they glow.

The sun is hotter than some stars and cooler than others. The sun, like some stars, is yellow. Other stars are white, blue, or red. Still others are dark and don’t glow at all. In size, the sun is an average star. It is bigger than some stars and smaller than others. The picture at the left shows how much bigger than Earth the sun is. Look at the pictures on the next page to learn about the parts of the sun.
Size

The sun is a medium-sized star. The smallest stars may be 450 times smaller than the sun and have one-twentieth the sun's mass. The largest stars may be more than 1,000 times bigger than the sun and have up to 50 times more mass.

The sun's corona can be seen only when the center of the sun is covered. In a solar eclipse, the moon passes between the sun and Earth, blocking light from the bright center part of the sun.

Convection Zone

Currents of hot gases carry energy as they rise to the surface and then sink.

Core Temperature

Deep inside the sun the temperature is 15,000,000°C.

Corona

The corona surrounds the sun's surface. It is made of very hot, glowing gas. It has a temperature of about 2,000,000°C. The corona reaches millions of kilometers into space.

Surface

The total surface of the sun is about 12,000 times greater than the surface of Earth. The sun's temperature at the surface is less than 6,000°C. Loops, flares, and arching jets of gas occur on the sun's surface.
Distances in Space

Scientists use kilometers as a unit to measure distances from one place to another on Earth. Using kilometers to measure distances to the stars would be very awkward. The distance to the nearest star outside the solar system, called Proxima Centauri, is about 40,678,000,000,000 kilometers! You learned that astronomical units, or AUs, are used to measure distances to the planets. AUs are based on the distance from Earth to the sun. But AUs are not big enough to be useful to measure distances to the stars. Instead, scientists use a unit based on the speed of light to measure these distances.

On Earth, light travels so fast it seems to take no time at all to get where it's going. It travels 300,000 kilometers in a second. Light travels so fast that it could circle Earth seven times in a second. In one year, light travels as far as 9,500,000,000,000 kilometers. That distance is called a light year. It is used as a unit to measure distances in space.
The stars are so far away from Earth that light from Proxima Centauri, the closest star, takes 4.3 years to reach Earth. Suppose you could look at that star in the sky right now. You would see light that left the star more than 4 years ago.

Some stars are much farther away. Find the star Cassiopeia A in the star group called Cassiopeia shown at the right. Light from this star travels for 11,000 years before it reaches Earth. When you see that star in the sky, you see light that left it 11,000 years ago. How many light years away from Earth is Cassiopeia A? Light from the sun, shown below, takes only 8 minutes to reach Earth.

**Cassiopeia A**
Light from the star named Cassiopeia A travels for 11,000 years before it reaches Earth.

**The Sun**
Light from the sun takes 8 minutes to reach Earth. Any time you see sunlight shining on Earth, you are observing light that left the sun about 8 minutes ago.

**Proxima Centauri**
Other than the sun, Proxima Centauri is the star closest to Earth. It is seen in a group of stars called Centaurus.
The Properties of Stars

Astronomers group stars by their properties, such as brightness, color, and size. These properties can depend on other characteristics, such as temperature.

Some stars are so bright you can see them on almost any night, even in a lighted city. Others are so faint they can be seen only through a telescope. A star’s brightness depends on how big the star is, how hot it is, and how far away from Earth it is.

The bigger and hotter the star, the more light it gives off. However, its brightness also depends on its distance from Earth. Imagine looking at a row of streetlights on a dark night. They all give off the same amount of light. However, a streetlight that is close to you looks brighter than one that is far away. In the same way, a star that is nearer Earth looks brighter than one that gives off the same amount of light but is farther away.

A star’s color depends on its temperature. The pictures show how a steel bar changes color from red, to orange, to yellow, to white or blue-white when it is heated in a furnace. In a similar way, stars give off a red, orange, yellow, white, or blue-white glow, depending on their temperature. Red stars are the coolest. The sun gives off a yellow glow because it is a medium-hot star. Blue-white stars are the hottest.
Look at the picture of the group of stars on the right above. This group is known as Orion. Notice that it includes stars of several different colors. The large reddish star is Betelgeuse, one of the stars in the chart below. Some of the stars in Orion are blue and some are white.

Stars range greatly in size. The smallest stars are even smaller than Earth. Recall that the sun is an average star and that its diameter is 100 times Earth’s diameter. Betelgeuse is 500 times bigger than the sun. Other large stars can be as much as 1,000 times the diameter of the sun. Some stars vary in size. One of these is Polaris, also known as the north star. Polaris is actually three stars close together that move around each other in space. The chart shows the properties of several stars, including the sun.

<table>
<thead>
<tr>
<th></th>
<th>Sirius</th>
<th>Polaris</th>
<th>Betelgeuse</th>
<th>Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Blue</td>
<td>Orange</td>
<td>Red</td>
<td>Yellow</td>
</tr>
<tr>
<td>Diameter</td>
<td>4,300,000 km</td>
<td>Varies in size</td>
<td>640,000,000 km</td>
<td>1,400,000 km</td>
</tr>
<tr>
<td>Temperature</td>
<td>More than 9,000°C</td>
<td>5,700°C</td>
<td>3,000–3,500°C</td>
<td>Less than 6,000°C</td>
</tr>
</tbody>
</table>
Constellations and Galaxies

When you look at the stars, the brightest ones seem to form patterns or groups in the sky. Most people have seen groupings known as the Big Dipper, the Little Dipper, Cassiopeia, Orion, and others. Stars that seem to be in a group make up a **constellation**.

People in ancient times told stories about the constellations they saw. Different groups of people made up different stories. For example, look at the group of stars called the Big Dipper in the star map on the left. The star group looks like a dipper, with a bowl and a handle. Greeks saw these stars and others near them as a Great Bear. Ancient Romans saw the constellation as a team of oxen pulling a plow. The ancient Babylonians thought the Big Dipper looked like a wagon. Make up your own story for a group of stars you can see.

Stars in constellations are not really close together in space. They only look that way when viewed from Earth. The pictures below show how the constellation Cassiopeia looks from Earth and how it would look if you could see it from somewhere in space.

▲ **Cassiopeia Viewed from Earth**
The constellation Cassiopeia looks like a W as you look overhead and slightly north in December.

▲ **Cassiopeia Viewed from Space**
From space, the stars in Cassiopeia would seem to be in different positions, so the grouping would look different.
The stars in a constellation only look like a group in space. However, huge numbers of stars really are clustered in groups, called galaxies. In a galaxy, gas, dust, and hundreds of billions of stars are all fairly close together in space. Some bright spots you see in the night sky are not single stars, but distant galaxies. They are so far away, they look like faint stars. The pictures to the right show how distant galaxies look when recorded by a telescope on a satellite in space.

The solar system is located near the edge of the Milky Way Galaxy. Look at the picture above of the cloud of billions of stars called the Milky Way. The stars in the Milky Way lie between the sun and the edge of the Milky Way Galaxy.

**Lesson 2 Review**

1. How does the sun compare to other stars?
2. What units do scientists use to measure distances in space?
3. What properties do scientists use to group stars?
4. Compare a galaxy and a constellation.

**Place Value Through Millions**

The sun measures 1,392,000 kilometers in diameter. Write this number in expanded form and in words.
Making a Spectroscope

Getting Ready
In this activity you will make and use a spectroscope to separate light from a bulb into the colors of the visible spectrum.

Follow This Procedure
1. Make a chart like the one shown. Use your chart to record your prediction, observations, and drawing.

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Observations</th>
<th>Drawing</th>
</tr>
</thead>
</table>

2. Put on your safety goggles. Use one end of the paper towel tube to trace two circles on the sheet of cardboard. Cut them out with the scissors.

3. Cut one of the circles in half. Tape the halves to one end of the tube with a little space between them to make a narrow slit. Do not cover the slit with the tape, but seal all other spaces (Photo A).

4. With a sharp pencil, punch a hole in the center of the other cardboard circle. Cover the hole with the diffraction grating. Tape the circle and diffraction grating to the other end of the cardboard tube (Photo B).

Self-Monitoring
Except for the slit and small hole, have I sealed all of the edges with tape so no light comes into the tube?
Interpret Your Results

1. Look at the drawing of the color patterns you drew. Have you seen a pattern like this before? If so, where?

2. Explain how the diffraction grating in the spectroscope changes the light from the light bulb.

Inquire Further

What patterns do other sources of light produce when viewed with the spectroscope? Develop a plan to answer this or other questions you may have.

Self-Assessment

- I followed instructions to make a spectroscope.
- I predicted how light would appear when looking through the spectroscope.
- I observed light from a bulb through the spectroscope.
- I recorded my prediction and observations, and made a drawing.
- I explained how the diffraction grating in a spectroscope changes the light from a light bulb.

Photo B

A deflective grating works like a prism. Predict how the light will appear when you look at the light bulb through the spectroscope. Record your prediction in your chart.

6. Point the slit of the spectroscope at the light bulb. Look through the small hole and diffraction grating at the other end (Photo C). Record your observations and draw a picture of what you see.

Safety Note: Do not look at the sun with your spectroscope.

Photo C

A girl is holding a homemade spectroscope.
Lesson 3

How Do Scientists Study Planets and Stars?

You will learn:
- how scientists use spectroscopes to analyze light.
- how telescopes work.
- how images from telescopes are recorded.
- why scientists use telescopes in space.

You peer through binoculars at a tree far away. The tree looks close, and you can see it more clearly. The binoculars make it look larger! In a similar way, scientists use powerful telescopes to observe objects in space.

Analyzing Light

Astronomers study objects in space by observing the light and other forms of radiation they give off. To do this, they use special tools to record, focus, magnify, and analyze the light and other radiation. To analyze something is to separate it into its parts so it can be studied.

Notice how the prism splits white light into all the colors of the rainbow. A spectroscope is a tool that scientists use to analyze light. It can separate light from a glowing star into bands or patterns of light. Each element present in the star has its own pattern. The picture below shows the pattern a spectroscope makes when it analyzes glowing hydrogen. Astronomers study the patterns the spectroscope makes to find out what elements a star contains.

Glossary

spectroscope (spekˈtro skəp), an instrument that separates light into a pattern of lines of different colors.

A prism separates white light or sunlight into a rainbow spectrum, or pattern of colors.
Telescopes

Telescopes make distant objects look clearer and show detail. Do you know how they do it? Mirrors and lenses in telescopes bend and focus light to produce an image with more detail.

If you have used binoculars or a hand lens, you know that a lens can magnify objects. You may also know that the lens in your eye focuses light and produces an image. Some people's eyes do not form a clear image. Specially shaped lenses in eyeglasses can help the eye focus.

Refraction and reflection are two different ways to gather and focus light. Lenses work by **refraction**, or the bending of light as it passes from one material to another. Notice in the pictures below that the way light bends as it passes through a lens depends on the shape of the lens.

Mirrors work by **reflection**, or bouncing light off a surface. The pictures to the right show that the shape of a mirror changes the direction of light that bounces off it.

**Lenses**

The shape of a lens determines the angle of bending and where the light rays that pass through it focus. Trace the bending of light by the lenses in the pictures.

![Light Rays](image)

- A convex lens is thicker in the middle and thinner at its edges. It brings light rays together at one point. The thicker the lens, the more it bends the light rays and the closer to the lens the focus point will be.

- A concave lens is thinner in the middle and thicker at the edges. It makes light rays spread apart.

**Glossary**

- **refraction** (ri frak'shan), the bending of light as it passes from one material to another; a way to gather and focus light

- **reflection** (ri flek'shan), the bouncing of light off a surface; a way to gather and focus light

**Mirrors**

The image in a mirror is formed by reflection, the bouncing of light off a shiny surface. Use your fingers to trace the direction the mirrors in the pictures make the light bounce.
Refracting Telescope
This refracting telescope works like binoculars do. A large convex lens at the end of the telescope captures light from the stars and bends it to focus on an image. A convex lens in the eyepiece magnifies the image for viewing.

Optical telescopes produce images by focusing light rays. They work by either refraction or reflection. The diagrams on these two pages are basic patterns of how refracting and reflecting telescopes work. Use your fingers to trace the path of light in each kind of telescope. Find where the light enters the telescope. Follow it to where it passes through the eyepiece and to the observer. The earliest telescopes, like Galileo’s telescope in the picture below, were refracting telescopes.

Galileo’s Refracting Telescope
Galileo built many refracting telescopes. He observed things that no one had seen before, including moons of Jupiter and the craters on Earth’s moon. He saw ten times as many stars as anyone had ever seen before.
The first important discovery made with a refracting telescope was that there are craters on the moon. The discovery was made in 1609 by the Italian astronomer Galileo. In 1668, Isaac Newton designed a reflecting telescope like the one shown below. It solved a problem with blurred images that Galileo had with his telescope. More complex designs used today include large reflecting telescopes that have many small, six-sided mirrors mounted close together, instead of one large mirror.

**Reflecting Telescope**

This reflecting telescope uses mirrors to bounce light and form a clear image. A concave mirror magnifies and focuses an image toward a flat mirror, which then reflects it toward an eyepiece. A convex lens in the eyepiece focuses the image for viewing.

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**Newton’s Reflecting Telescope**

Sir Isaac Newton invented the reflecting telescope. Many astronomers still use telescopes based on Newton’s design.
Visible light waves are only one kind of radiation that stars and other objects in space give off. Other kinds of radiation cannot be seen by the human eye. The wavelengths are shorter or longer than visible light. This means they are too short or too long for the eye to detect. Scientists use special telescopes, as well as satellites in space, to collect and make images from these invisible kinds of radiation.

A radio telescope, like the one in the picture below, collects and measures the radio waves that objects in space give off. Radio telescopes have been used to discover objects that optical telescopes cannot see, such as dust clouds in dark parts of the sky. The image of the Whirlpool Galaxy above was taken by a radio telescope.

Infrared rays have longer wavelengths than visible light. An infrared telescope like the one above collects infrared rays from objects in space. An infrared telescope is built like a reflecting telescope. However, it has an infrared detector instead of an eyepiece. The picture above of the Milky Way Galaxy was taken by an infrared telescope on a satellite in space.
Recording Images

To record images from optical telescopes, astronomers often use film or photographic plates. Film can be exposed for a long time, so it can collect enough light to make dim objects appear bright. The camera attaches to the eyepiece of the telescope and collects light on film during long, "elapsed-time" exposures. It can record objects that might be too faint for the eye to see, even through a telescope.

The pictures below were taken with a camera attached to a telescope. Compare how many stars you can see in each picture. The first picture, exposed for 12 seconds, shows only a few stars. In the second picture, exposed for 2 minutes, more stars are visible. The third picture, exposed for 8 minutes, shows hundreds of stars, as well as dust and gases. The increased exposure time has brought out a great deal of detail about the part of the sky shown.

Electronic detectors are also used with all types of telescopes to record images from space. These instruments collect light or other rays and change their radiation pattern into a pattern of electrical charges. Then the pattern can be shown as a picture on a computer screen. Different wavelengths of radiation may be shown in different colors. The colors may not be the real colors of the dust clouds and other objects in space. However, the colors help scientists understand the image. For example, places or objects that have different temperatures can be shown in different colors.

The telescope was aimed at the constellation Sagittarius.
This unusual star exploded 150 years ago and has divided into two sections. It is 100 times more massive than the sun.

Telescopes in Space

Telescopes on rockets or satellites in space, such as the Hubble Space Telescope on the left, have an advantage over telescopes on Earth. They can record light and other radiation from objects in space, without the radiation having to pass through Earth’s atmosphere. Telescopes on Earth often produce a blurred image as light passes through the atmosphere. The air contains many particles, including water vapor, dust, carbon dioxide, and other substances. Also, in some places the air is warm or hot; in other places it is cool or cold. All these things affect the way light moves through air. They keep a lens from focusing an image clearly. The pictures of objects in space on these two pages were taken by the Hubble Space Telescope from far outside Earth’s atmosphere.

When studying infrared rays from objects in space, even heat absorbed by the telescope itself can affect the image being recorded. For this reason, infrared telescopes have to be cooled, even in the extreme cold of space. Water vapor and carbon dioxide gas in Earth’s atmosphere block many infrared rays. To avoid blurred images, infrared telescopes are usually placed on very high mountains or on satellites.

Two rings of glowing gas surround a place where a star exploded.
This butterfly nebula has a central star and continually expanding “wings” of gases. In this false-color image, different gases are shown in different colors.

The Hubble Space Telescope was launched in 1990. It observes objects in space from above the Earth’s atmosphere. It contains a 2.4-meter reflecting telescope. It also has cameras, supersensitive radiation detectors, and spectroscopes. It can collect and make images of infrared, visible, and ultraviolet rays from objects, and it can record bright images of very faint objects. It produces much clearer images than telescopes on Earth can produce.

Lesson 3 Review

1. What do scientists learn from using spectroscopes to analyze light?
2. How do telescopes work?
3. How are images from a telescope recorded?
4. Why do telescopes in space produce better images than those on Earth?
5. Compare and Contrast
   How are refraction and reflection alike?
   How are they different?

△ The orange-colored blobs in the picture are two colliding galaxies.

△ These three columns of dust and gas are located in the Eagle Nebula. Hot, massive stars heat the surrounding gas, making it glow. Scientists estimate that this nebula is 2,000,000 years old.
## Investigating Lenses

### Process Skills
- observing
- making operational definitions

### Materials
- lens paper
- glass convex lens
- plastic hand lens

### Getting Ready
In this activity you can find out how convex lenses change the way objects appear. Then you can use lenses to make a simple telescope.

### Follow This Procedure

1. Make a chart like the one shown. Use your chart to record your observations.

<table>
<thead>
<tr>
<th>Description of lens shape</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing of lens</td>
<td></td>
</tr>
<tr>
<td>Change caused by glass convex lens</td>
<td></td>
</tr>
<tr>
<td>Change caused by smaller convex lens</td>
<td></td>
</tr>
<tr>
<td>Appearance of object through telescope</td>
<td></td>
</tr>
</tbody>
</table>

2. Place a piece of lens paper around the glass convex lens. Carefully feel the shape of the lens. What is the shape of the lens? Record your observations. Then draw a side view of the lens in your chart.

3. **Safety Note** Use care when handling the glass lens.

   Hold the glass convex lens near to your eye. Looking through the lens, hold the index finger of your other hand out at arm’s length. Bring your finger toward the lens until it is in focus (Photo A). How does the lens change the way your finger looks? Record your observations.

4. Repeat step 3 using the smaller convex lens of the hand lens. Which lens made your finger look larger? Record your observations.
5 Now you will make a simple telescope. Hold the small lens of the hand lens near your eye. Hold the glass convex lens in front of the hand lens so you can see through both of them.

6 Face a distant object. Move the glass lens back and forth until the distant object comes into focus (Photo B). You have just made and focused a simple refracting telescope. How does the object appear through your telescope? Record your observations.

Safety Note Never look through lenses at direct sunlight or other very bright sources of light.

Interpret Your Results

1. Write an operational definition of a convex lens. Be sure to include how the lens is shaped and how objects appear when viewed through the lens.

2. Describe how to make and use a simple refracting telescope. Describe how to place the lenses and how to focus the telescope. Describe how objects appear when viewed through the telescope.

Inquire Further

What happens if you use a concave lens as the eyepiece of a simple refracting telescope? Develop a plan to answer this or other questions you may have.

Self-Assessment

- I followed instructions to record observations of objects viewed through convex lenses.
- I drew a diagram of a convex lens.
- I followed instructions to make and use a simple refracting telescope.
- I wrote an operational definition of a convex lens.
- I described how to make and use a simple refracting telescope.
Chapter 4 Review

Chapter Main Ideas

Lesson 1
- As better tools enabled scientists to learn more about the solar system, they developed new models.
- The nine planets that move around the sun are different in size, atmosphere, distance from the sun, and number of moons.
- The sun, planets, asteroids, meteoroids, and comets are objects in the solar system.
- Objects in the solar system can affect Earth if they enter Earth’s atmosphere, if their radiation or energy reaches Earth, and through the effect of gravity on the tides.

Lesson 2
- The sun is an average star in size, brightness, and temperature.
- Scientists measure distances to stars and galaxies in units called light years, the distance light can travel in a year.
- Scientists group stars by their size, brightness, and color.
- Constellations are groups of stars that appear to be near each other; galaxies are huge groups of stars that actually are fairly close to each other.

Lesson 3
- Spectroscopes identify the elements in a star by separating starlight into a pattern of lines and colors.
- Lenses and mirrors in telescopes focus light and magnify images.
- Images from a telescope can be recorded on film or by electronic detectors.
- Light and other radiation that is recorded by telescopes in space do not pass through the atmosphere, which could blur the image.

Reviewing Science Words and Concepts

Write the letter of the word or phrase that best completes each sentence.

a. asteroid
b. comet
c. constellation
d. elliptical
e. galaxy
f. light year
g. meteor
h. meteorite
i. meteoroid
j. model
k. reflection
l. refraction
m. spectroscope

1. The distance light can travel in a year is called a ___.
2. A group of stars that forms a pattern in the sky is a ___.
3. A ball of ice, dust, and gases that revolves around the sun in a long, thin orbit is a ___.
4. A piece of rock from space that passes through the atmosphere and lands on Earth is a ___.
5. A streak of light that passes through the atmosphere is a ___.
6. A ___ is an instrument that identifies substances by separating the light they give off into patterns of lines and colors.

7. A large rocky object that revolves around the sun is an ____.

8. A ___ shows how something looks or works.

9. The bouncing of light off a shiny surface is ____.

10. An orbit that is shaped like a flattened circle is ____.

11. A piece of rock or metal that revolves around the sun is a ____.

12. The bending of light as it passes from one substance to another is called ____.

13. A huge group of stars in space, along with dust and gases, makes up a ____.

2. Suppose you look into the sky on a dark, clear night. List the different things you would expect to observe.

3. Suggest a way to make a model of what could happen when a meteorite lands on Earth. List the materials you would use and tell how you would use them.

Critical Thinking

1. Compare and contrast what you might see if you looked at a distant galaxy through a telescope on Earth with what you might see in an image of the galaxy sent to Earth by a camera on a satellite in space.

2. Suppose you see a large crater in Earth’s surface. Make a hypothesis to explain how it might have formed, and tell what evidence you would look for to support your hypothesis.

3. Predict what you might see in the sky if Earth passed through the tail of a comet.

Explaining Science

Draw and label a diagram or write a paragraph to answer these questions.

1. How is the orbit of a comet different from the orbit of a planet?

2. In what two ways are AU’s and light years different?

3. How are radio telescopes and infrared telescopes different from optical telescopes?

Using Skills

1. The star Sirius is 4,300,000 kilometers in diameter. Show that you understand place values through millions by writing this number two other ways.
Unit C Review

Reviewing Words and Concepts

Choose at least three words from the Chapter 1 list below. Use the words to write a paragraph about how these concepts are related. Do the same for each of the other chapters.

Chapter 1
- crust
- deposition
- erosion
- mantle
- plate
- weathering

Chapter 2
- acid rain
- carbon monoxide
- fossil fuel
- nonrenewable resource
- ozone

Chapter 3
- climate
- condense
- evaporate
- greenhouse gases
- infrared radiation
- precipitation

Chapter 4
- asteroid
- comet
- meteoroid
- constellation
- galaxy
- light year

Reviewing Main Ideas

Each of the statements below is false. Change the underlined word or words to make each statement true.

1. The **lithosphere** is the layer of gases that surrounds Earth.
2. The hot, central part of Earth is the mantle.
3. **Deposition** is the process of breaking down and changing rock.
4. A resource that can be replaced within a short time is a **fossil fuel**.
5. A mineral is an unwanted substance in the air or water.
6. In the **greenhouse effect**, water in its different forms moves through the land, air, and water on the earth.
7. The tilt of the earth affects how much sunlight a place gets at different times and causes the **ocean currents**.
8. Astronomers usually measure distances to the stars in kilometers.
9. A star’s color indicates its brightness.
10. A group of stars clustered together in space is a **constellation**.
Interpreting Data

The following chart provides information about the properties of some stars. Use the chart to answer the questions below.

<table>
<thead>
<tr>
<th>Color</th>
<th>Diameter</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sirius</td>
<td>Blue</td>
<td>4,300,000 km</td>
</tr>
<tr>
<td>Polaris</td>
<td>Orange</td>
<td>Varies in size</td>
</tr>
<tr>
<td>Betelgeuse</td>
<td>Red</td>
<td>640,000,000 km</td>
</tr>
<tr>
<td>Sun</td>
<td>Yellow</td>
<td>1,400,000 km</td>
</tr>
</tbody>
</table>

1. Of the stars shown on the chart, which is the hottest?
2. Which star is coolest?
3. Put the star colors in order from hottest to coolest.
4. Astronomers group stars by their color and size. One group of stars are called red supergiants. Which of the stars on the chart might be a red supergiant?

Communicating Science

1. Write a paragraph explaining how scientists can use layers of rock to learn about how the earth has changed.
2. Write a paragraph explaining what events can occur at plate boundaries.
3. Draw and label a diagram that shows how the greenhouse effect keeps the earth warm.
4. Draw and label a diagram that shows how light bends when it passes through a lens.

Applying Science

1. Write a paragraph suggesting ways your community could better protect water or land resources.
2. Write a paragraph describing the climate in your area. Remember that climate is weather conditions over many years.
Unit C
Performance Review

Earth and Space Day
Using what you learned in this unit, complete one or more of the following activities to be included in an Earth and Space Day celebration. These activities will help people learn more about the earth and space.

Drama
Draw a picture of a constellation. You can use a star pattern in the sky or make one up. Make up a skit that tells the story of your constellation and act out the skit.

Science News
Write a news report that tells new things scientists are learning about objects in space. Sources of new information include telescopes, satellites, and spaceships.
Physics
Draw a diagram of the water cycle. Identify the steps where the water changes state. Show the arrangement of the particles of matter in each state. Use the diagram to explain how matter changes state.

Safety
Find out ways to stay safe during an earthquake. Draw a chart to report your findings. Use the chart to communicate what you learned to others.

Environment
Give a report on air pollution in your community. Tell what people could do to improve the quality of air and other resources in the environment.
Using a Graph to Write a Description

Using Graphs
Graphs can be useful ways of showing comparisons. The three most common types of graphs are the pie chart or circle graph, the bar graph, and the line graph. A pie chart or circle graph is used to show data as parts of a whole. A bar graph is used to compare similar things, such as the heights or weights of people. A line graph is usually used to show how one thing changes in response to another, such as how someone’s height changes over time. What kind of information is shown in each of the graphs below?

Make a Graph
In Chapter 1, you learned about the three layers that make up the Earth—the crust, the mantle, and the core. Use the information provided about the thickness of each layer to calculate the percentage of the Earth each layer makes up. Use the type of graph you think is most appropriate to display this data. Be sure to label your graph clearly and give it a title.

Write a Description
Use your graph and information from the chapter to write a three-paragraph description of the three layers of the Earth. Include information about the characteristics of each layer and tell how much of the Earth each layer makes up. Use one paragraph to describe each layer.

Remember to:
1. Prewrite Organize your thoughts.
2. Draft Write your description.
3. Revise Share your work and then make changes.
4. Edit Proofread for mistakes and fix them.
5. Publish Share your description with your class.