DISCOVERING SCIENCE 8 TEACHER'S RESOURCE

UNIT 2: OPTICS

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McGraw-Hill Ryerson

UNIT 2: OVERVIEW

Cameras, binoculars, eyeglasses, and our own human vision system all depend on predictable properties of light. Ancient societies developed models to help predict the properties of light. We have been refining those models, and developing technologies based on them, ever since.

Chapter 4: Many properties of light can be understood using a wave model of light.

Early philosophers believed that light was made of particles. The particle model of light helped them to explain some of light's properties, and enabled them to develop technologies such as magnifying glasses, reading glasses, microscopes, and telescopes. By the 1800s, however, scientists realized that the particle model of light could not explain all of light's properties, and therefore, the particle model was supplanted by the wave model. This new model allowed scientists to explain such phenomena as light bending around corners, travelling through a vacuum, and passing through narrow openings. As students learn about the refinement of our understanding of light, they are also led to appreciate the value and the flexibility of all models in science. In fact, today we usually use waves to model light, but as our understanding continues to develop, the model for light continues to evolve.

The wave model of light is a useful one for students. As students explore some of the properties of waves, they will develop an understanding of many of the properties and behaviours of light. Students will experiment with white light to see the colours of which it is made. They will learn how other types of electromagnetic radiation—including X rays, microwaves, and ultraviolet rays—are similar to, and different from, visible light. They will also read about the special applications that have been developed for each of these types of waves.

Chapter 5: The law of reflection allows mirrors to form images.

The wave model of light represents most of light's properties accurately; however, to understand reflection and refraction, it is helpful to think of light as rays. Ray diagrams can be drawn to explain and predict the behaviour of light when it encounters an obstacle, a reflective surface, or an interface between materials of differing densities, for example, air and water. Students use hands-on investigations as well as ray diagrams to explore the laws of reflection. When a ray of light meets a mirror, the angle of incidence (the angle between the ray and a line perpendicular to the mirror) is always equal to the angle of reflection (the angle between the reflected ray and a line perpendicular to the mirror). Curved mirrors result in different types of images than flat mirrors or plane mirrors do, but they all obey this basic law of reflection. By following this law, students will use ray diagrams to predict the location and size of an image in a curved or plane mirror.

Students also learn how to use ray diagrams to understand and predict the results of refraction. When a ray of light moves from one medium to another that is denser than the first, it always bends, or refracts, toward the normal (toward a line perpendicular to the interface). A similar effect can be observed if rows of a marching band walk from concrete onto soft ground (at an angle other than 90°). The end of each row of bandmembers that reaches the soft ground first will slow down, and the direction of the entire band will shift slightly. If a ray of light moves from one medium to another that is less dense, it always bends away from the normal.

Chapter 6: Lenses refract light to form images.

One of the most important applications of refraction is the lens. Microscopes, telescopes, eyeglasses, and cameras are all based on the refraction of light through a lens. The lenses in our own eyes adjust to refract the light coming from different distances in order to create clear images on our retinas. Using ray diagrams, students learn that concave lenses cause light rays to spread out, and convex lenses cause light rays to converge. Students learn that an object's image viewed through a concave lens is always smaller than the object, and that the size of an object's image viewed through a convex lens depends on the distance the object is from the lens. Students investigate this pattern by building a small projector and a pinhole camera.

Much can be learned about the human eye by considering how lenses refract light. Indeed, students apply what they have learned about lenses to consider far-sightedness, near-sightedness, and astigmatism. Using the wave model of light, they consider how our rod and cone cells enable us to see shapes and colours.

Although optical devices such as cameras, binoculars, and microscopes have different purposes, they are based on very similar technology. Each one consists of lenses and mirrors to manipulate light rays. By examining detailed diagrams of each device, students compare and contrast how these instruments function. In the Unit Project, students apply what they have learned about the application of mirrors and lenses to build an optical instrument of their own.

MULTIPLE INTELLIGENCES CORRELATION FOR UNIT 2 ACTIVITIES AND INVESTIGATIONS

The table below identifies possible multiple intelligences that could be incorporated into activities and investigations in this unit. For more information about differentiated instruction and multiple intelligences, see the Introduction and Implementation section in this Teacher's Resource.

MULTIPLE INTELLIGENCES:	VL	VS	BK	MR	LM	N	E	IA	IE
UNIT 2: OPTICS									
Find Out Activity: Light is Energy		■							
Chapter 4: Many properties of light can be understood using a wave model of light.									
Find Out Activity 4-2A: Watching Water Waves		■				■			
Think About It Activity 4-2B: Frequency Formula					■				
Find Out Activity 4-2C: Catch a Waveform		■		■					
Conduct an Investigation 4-2D: Wire Waves		■	■		■				
Find Out Activity 4-3A: Rainbows of Light		■							
Find Out Activity 4-3B: Colour Your Rainbow		■							
Find Out Activity 4-4A: Seeing the Invisible		■							
Find Out Activity 4-4B: Reflection in the Infrared		■							
Find Out Activity 4-4C: Sunscreen Circles		■							
Chapter 5: The law of reflection allows mirrors to form images.									
Find Out Activity 5-1A: Absorb, Reflect, Transmit		■			■				
Find Out Activity 5-1B: Observing Refraction		■							
Find Out Activity 5-1C: When Light Reflects		■							
Core Lab Conduct an Investigation 5-1D: Follow That Refracted Ray!		■			■				■
Find Out Activity 5-2A: Reflections of Reflections		■			■				
Core Lab Conduct an Investigation 5-2B: Demonstrating the Law of Reflection		■			■				
Core Lab Conduct an Investigation 5-2C: Applying the Law of Reflection		■							
Find Out Activity 5-3A: Reflection from a Spoon		■							
Conduct an Investigation 5-3B: Real and Virtual Images		■							■
Chapter 6: Lenses refract light to form images.									
Find Out Activity 6-1A: Lenses and Light Rays		■							
Find Out Activity 6-1B: The Focal Length of a Convex Lens		■							
Find Out Activity 6-1C: Make a Model of a Projector		■							
Conduct an Investigation 6-1D: Pinhole Camera		■							
Find Out Activity 6-2A: Changing Colours			■						
Think About It Activity 6-2B: What Colours Do Rod and Cone Cells Detect?					■				
Think About It Activity 6-2C: Being Blind		■							■
Conduct an Investigation 6-2D: Dissecting a Sheep Eye		■							
Find Out Activity 6-3A: Experimenting with a Simple Lens		■							
Think About It Activity 6-3B: Microscopes on the Job									■
Unit 2 Project: Building an Optical Device		■							■
Unit 2 Integrated Research Investigation: Mirrors for Reflecting Telescopes		■							

Multiple Intelligence codes:
VL = Verbal-Linguistic Intelligence; VS = Visual-Spatial Intelligence; BK = Body-Kinesthetic Intelligence; MR = Musical-Rhythmic Intelligence; LM = Logical-Mathematical Intelligence; N = Naturalist Intelligence; E = Existential Intelligence; IA = Intrapersonal Intelligence; IE = Interpersonal Intelligence

Planning Chart for Activities and Investigations for Unit 2: Optics

ACTIVITY/ INVESTIGATION	ADVANCE PREPARATION	APPARATUS/MATERIALS	TIME REQUIRED
Unit 2: Optics			
Find Out Activity: Light is Energy	1 week before: – Gather solar calculators or remind students to bring them from home for the day of the activity.	For each pair: – solar calculator without a backup battery or with the battery disabled	• 10 min
Chapter 4: Light is a form of electromagnetic waves.			
Find Out Activity 4-2A: Watching Water Waves	1 day before: – Gather materials.	For each group: – pie plate – water – pencil	• 15 min
Think About It Activity 4-2B: Frequency Formula	1 day before: – Make copies of BLM 2-10, Frequency Formula (optional).	None	• 15 min
Find Out Activity 4-2C: Catch a Waveform	1 day before: – Gather materials.	For each group: – felt pen – metre stick – C clamp – cardboard or manila card stock (Have some spare pieces on hand.) – masking tape	• 25 min
Conduct an Investigation 4-2D: Wire Waves	1 day before: – Gather materials. – Make copies of BLM 2-11, Wire Waves (optional).	For each group: – coiled metal spring – piece of masking tape or string	• 30 min
Find Out Activity 4-3A: Rainbows of Light	1 day before: – Gather materials. – Make copies of BLM 2-12, At the End of the Rainbow.	For each group: – flashlight – glass prism – water – dishwashing liquid – BLM 2-12, At the End of the Rainbow	• 15 min
Find Out Activity 4-3B: Colour Your Rainbow	1 week before: – Ask students to bring in old CDs. 1 day before: – Gather materials. – Make copies of BLM 2-15, What is Colour?	For each group: – CD – coloured filters – coloured pencils or felt pens – white light source – BLM 2-15, What is Colour?	• 20 min
Find Out Activity 4-4A: Seeing the Invisible	2 days before: – Gather materials.	For each group: – beaker – tonic water – black light – SPF 30 sunscreen – Canadian currency bill	• 25 min
Find Out Activity 4-4B: Reflection in the Infrared	2 days before: – Gather materials. Day of instruction: – Obtain access to a television with remote control, and a freezer.	For each group: – television set with remote control – variety of materials such as cardboard, aluminum foil, paper, glass, cloth, mirror – freezer	• 25 min
Find Out Activity 4-4C: Sunscreen Circles	2 days before: – Gather materials.	For each group: – paper – yellow felt pen – yellow highlighter – vegetable oil – SPF 30 sunscreen – black light	• 30 min

ACTIVITY/ INVESTIGATION	ADVANCE PREPARATION	APPARATUS/MATERIALS	TIME REQUIRED
Chapter 5: The law of reflection allows mirrors to form images.			
Find Out Activity 5-1A: Absorb, Reflect, Transmit	2–3 days before: – Gather materials. – Place milk in a refrigerator. – Obtain access to an overhead projector for the activity.	For each group: – variety of objects, such as a block of wood; thin and thick blocks of wax; prisms of tinted, frosted, and clear glass or Plexiglass; petri dishes of water, milk	• 15 min
Find Out Activity 5-1B: Observing Refraction	1 month before: – Order ray boxes, if necessary. 1 day before: – Gather materials. – Remind students to bring rulers, pencils, and protractors.	For each group: – block of glass or transparent plastic – ray box – ruler – protractor – piece of white paper	• 25 min
Find Out Activity 5-1C: When Light Reflects	1 day before: – Gather materials. – Make copies of BLM 2-24, How Do Two-way Mirrors Work?	For each individual or pair: – clear plastic cup – water – paper – ruler – wooden pencil – BLM 2-24, How Do Two-way Mirrors Work?	• 15 min
Core Lab Conduct an Investigation 5-1D: Follow That Refracted Ray!	2 weeks before: – Have students collect and bring in transparent plastic box tops. 1 day before: – Gather other materials. – Remind students to bring rulers, pencils, and protractors.	For each group: – ray box – sheet of white paper – transparent plastic watertight tray (for example, the plastic top from a box of greeting cards) – ruler – protractor – water – vegetable oil – rubbing alcohol	• 40 min
Find Out Activity 5-2A: Reflections of Reflections	1 day before: – Gather materials. – Remind students to bring protractors.	For each group: – 2 plane mirrors – protractor – masking tape – paper clip	• 20 min
Core Lab Conduct an Investigation 5-2B: Demonstrating the Law of Reflection	1 week before: – Gather small objects (shorter than the mirror) with a pointed end, such as a pencil or nail. 1 day before: – Gather other materials. – Remind students to bring protractors and rulers. – Make copies of BLM 2-28, Plane Mirror Template (optional)	For each group: – ray box – small plane mirror (about 5 cm by 15 cm) with support stand – small object with a pointed end – protractor – ruler – pencil – sheet of blank paper – BLM 2-28, Plane Mirror Template (optional)	• 30 min
Core Lab Conduct an Investigation 5-2C: Applying the Law of Reflection	1 day before: – Gather materials. – Remind students to bring protractors and rulers.	For each group: – ray box – small plane mirror with support stand – protractor – ruler – pencil – sheet of blank paper	• 40 min
Find Out Activity 5-3A: Reflection from a Spoon	1 week before: – Purchase a set of kitchen spoons or ask students to each bring one from home.	For each individual or group: – kitchen spoon	• 10 min
Conduct an Investigation 5-3B: Real and Virtual Images	1 month before: – Purchase concave mirrors of different curvature, flat mirrors, and convex mirrors. 1 day before: – Gather materials. Arrange to conduct the activity in a room with a window. – Make copies of BLM 2-35, Real and Virtual Images (optional).	For each group: – 3 concave mirrors with different curvatures – 1 flat mirror – 1 convex mirror – white cardboard for screen – room with a window	• 30 min

ACTIVITY/ INVESTIGATION	ADVANCE PREPARATION	APPARATUS/MATERIALS	TIME REQUIRED
Chapter 6: The law of refraction allows lenses to form images.			
Find Out Activity 6-1A: Lenses and Light Rays	1 day before: – Gather materials.	For each group: – ray box – concave lens – convex lens – printed page	• 20 min
Find Out Activity 6-1B: The Focal Length of a Convex Lens	1 day before: – Gather materials.	For each pair: – convex lens – ruler – masking tape – stiff white paper	• 10 min
Find Out Activity 6-1C: Make a Model of a Projector	A few days before: – Purchase unfrosted light bulbs. 1 day before: – Gather materials. – Make copies of BLM 2-40, Projector Arrows.	For each group: – sheet of paper – felt pen – beaker – water – convex lens – unfrosted light bulb (and sockets connected to power source) – BLM 2-39, Projector Arrows	• 25 min
Conduct an Investigation 6-1D: Pinhole Camera	1 month before: – Ask students to collect tubes of different diameters (from wrapping paper, paper towels, etc.). 1 day before: – Gather materials.	For each group: – 2 tubes of different diameters or make 2 tubes using tape and paper – adhesive tape (with frosty appearance, not clear) – scissors – aluminum foil – pushpin	• 20 min
Find Out Activity 6-2A: Changing Colours	None	None	• 5 min
Think About It Activity 6-2B: What Colours Do Rod and Cone Cells Detect?	None	None	• 20 min
Think About It Activity 6-2C: Being Blind	None	None	• 15 min
Conduct an Investigation 6-2D: Dissecting a Sheep Eye	Several weeks before: – Order the sheep eyes, as well as the dissection equipment if necessary. 1 day before: – Gather materials. – Prepare 10 percent bleach solution.	For each group: – preserved sheep eye – scissors – prod – dissection tray – protective gloves – paper towels – plastic disposal bag – 10 percent bleach solution	• 45 min
Find Out Activity 6-3A: Experimenting with a Simple Lens	1 day before: – Gather materials.	For each student or group: – glass test tube with stopper – water – paper or note card	• 10 min
Think About It Activity 6-3B: Microscopes on the Job	1 week before: – Arrange for access to computers and/or time at the library.	For whole class: – research materials	• 30 min research time • out-of-class time for additional research and to prepare the presentations • Additional time for presentations and the What Did You Find Out? questions

ACTIVITY/ INVESTIGATION	ADVANCE PREPARATION	APPARATUS/MATERIALS	TIME REQUIRED
Project: Building an Optical Device	2–3 days before: – Gather materials. – Remind students to bring a ruler and pencil for the activity. You might ask students to bring any cardboard boxes or tubes they might need from home.	For each group: – variety of lenses (convex and concave) – plane mirrors (one or more) – cardboard – tape – scissors – glue – ruler – pencil	• 15–30 minutes for brainstorming and/or research time • 30–45 minutes for collecting materials, and assembling and testing the device • Additional time for presentations
Integrated Research Investigation: Mirrors for Reflecting Telescopes	1 week before: – Arrange for computer lab or library time for student research. 1 day before: – Make copies of BLM 2-46, Make Your Own Glossary and BLM 2-47, Light Concept Map.	– BLM 2-45, Make Your Own Glossary – BLM 2-46, Light Concept Map	

TALKS AND TOURS

Speaker and field trip recommendations for Unit 2:

- To extend Activity 4-2C, Catch a Waveform, invite a music teacher or musician to demonstrate the sounds that a few common instruments make, and to talk with the class about the frequency of each sound's characteristic wave.
- A trip to a local theatre or high school to have a close-up look at stage lights and lenses and how they work could enhance the profile of a concert lighting designer in Career Connect.
- Invite an X-ray technician, radiologist, or another health care professional in to the classroom to talk about the uses and dangers of electromagnetic radiation in health care.
- A short walk in the neighbourhood can be turned into a hunt for different kinds of reflections. Challenge students to find as many as they can, and to look for patterns linking the type of reflection and the shape of the reflective surface.
- In Chapter 6, students learn how lenses and mirrors function in technologies that extend human vision. Students will probably already have some experience using microscopes, cameras, and binoculars, but a trip to a local observatory or a visit by an amateur astronomer could provide an introduction to telescopes, making learning about the optics of a telescope more interesting.

UNIT 2 BLACKLINE MASTERS

CONTENT-RELATED BLACKLINE MASTERS	ASSESSMENT-RELATED BLACKLINE MASTERS
Unit BLM 2-1, Unit 2 Summary BLM 2-2, Unit 2 Key Terms BLM 2-44, Make Your Own Glossary BLM 2-45, Light Concept Map BLM 2-46, Unit 2 Review	Assessment Checklist 6, Developing Models Assessment Checklist 9, Oral Presentation Assessment Checklist 10, Computer Slide Show Presentation Assessment Checklist 11, Poster Process Skills Rubric 1, Developing Models Process Skills Rubric 4, Problem Solving Assessment Rubric 3, Co-operative Group Work Assessment Rubric 7, Scientific Research Planner Assessment Rubric 8, Research Project Assessment Rubric 11, Communication Assessment Rubric 12, Using Tools, Equipment, and Materials Assessment Rubric 13, Multi-Media Presentation
Chapter 4 BLM 2-3, Chapter 4 Key Terms BLM 2-4, Chapter 4 Key Terms BLM 2-9, Riding the Waves BLM 2-10, Frequency Formula BLM 2-11, Wire Waves BLM 2-12, At the End of the Rainbow BLM 2-13, ROY G BIV BLM 2-14, Additive Primary Colours BLM 2-15, What is Colour? BLM 2-16, Setting the Stage BLM 2-17, Sunrise, Sunset BLM 2-18, Thermograms BLM 2-19, Chapter 4 Review	Assessment Checklist 1, Making Observations and Inferences Assessment Checklist 4, Laboratory Report Assessment Checklist 6, Developing Models Assessment Checklist 7, Scientific Drawing Assessment Checklist 13, Concept Map Assessment Checklist 15, Venn Diagram Assessment Checklist 17, Science Math Connect Assessment Checklist 24, K-W-L Assessment Checklist Process Skills Rubric 3, Controlling Variables Process Skills Rubric 5, Fair Testing Assessment Rubric 1, Concept Assessment Rubric 3, Co-operative Group Work Assessment Rubric 4, Scientific Drawing Assessment Rubric 5, Conduct an Investigation Assessment Rubric 11, Communication Assessment Rubric 12, Using Tools, Equipment, and Materials
Chapter 5 BLM 2-5, Chapter 5 Key Terms BLM 2-6, Chapter 5 Key Terms BLM 2-20, Absorb, Reflect, Transmit BLM 2-21, When Light Strikes BLM 2-22, Reflection: Ray Diagrams BLM 2-23, Refraction: Light Changes Direction BLM 2-24, How Do Two-way Mirrors Work? BLM 2-25, Mirror Images BLM 2-26, What You See is What You Get BLM 2-27, Sight Lines BLM 2-28, Plane Mirror Template BLM 2-29, Concave Mirror Template BLM 2-30, Convex Mirror Template BLM 2-31, Different Mirror Surfaces BLM 2-32, Egyptian Mirror BLM 2-33, Curved Mirrors: Images from a Distance Object BLM 2-34, Blind Spots in an Automobile BLM 2-35, Real and Virtual Images BLM 2-36, Chapter 5 Review	Assessment Checklist 1, Making Observations and Inferences Assessment Checklist 4, Laboratory Report Assessment Checklist 7, Scientific Drawing Assessment Checklist 12, Classification System Assessment Checklist 17, Science Math Connect Process Skills Rubric 2, Hypothesizing Process Skills Rubric 7, Predicting Process Skills Rubric 8, Interpreting Data Process Skills Rubric 10, Measuring and Reporting Assessment Rubric 3, Co-operative Group Work Assessment Rubric 4, Scientific Drawing Assessment Rubric 5, Conduct an Investigation Assessment Rubric 11, Communication Assessment Rubric 12, Using Tools, Equipment, and Materials
Chapter 6 BLM 2-7, Chapter 6 Key Terms BLM 2-8, Chapter 6 Key Terms BLM 2-37, Concave Lens Template BLM 2-38, Convex Lens Template BLM 2-39, Lenses and Light BLM 2-40, Projector Arrows BLM 2-41, Optical Illusions BLM 2-42, Making Things Bigger BLM 2-43, How Does It Work? BLM 2-44, Comparing an Eye with a Camera BLM 2-45, Chapter 6 Review	Assessment Checklist 1, Making Observations and Inferences Assessment Checklist 4, Laboratory Report Assessment Checklist 6, Developing Models Assessment Checklist 7, Scientific Drawing Assessment Checklist 9, Oral Presentation Assessment Checklist 12, Classification System Assessment Checklist 14, Events Chain or Flowchart Assessment Checklist 15, Venn Diagram Assessment Checklist 25, Safety Checklist Process Skills Rubric 1, Developing Models Process Skills Rubric 8, Interpreting Data Assessment Rubric 3, Cooperative Group Work Assessment Rubric 4, Scientific Drawing Assessment Rubric 5, Conduct an Investigation Assessment Rubric 7, Scientific Research Planner Assessment Rubric 8, Research Project Assessment Rubric 11, Communication Assessment Rubric 12, Using Tools, Equipment, and Materials

Teaching Notes
for
Pages 126 to 261 of the Student Textbook

UNIT 2 OPENER, pp. 126–127

The unit opening photograph features an astronomical observatory and a starry night sky. The glow from the stars makes the photograph look somewhat surreal because the observatory appears to be floating in space. This interesting effect was produced by shooting the scene using a telephoto lens on extreme magnification.

The photograph shows the idea of viewing the vastness of space with the largest instruments to do so. This photo, therefore, is an excellent introduction to the idea that humans use biological optical systems to produce visual images and construct technological optical systems to extend the limits of what we can see.

USING THE UNIT OPENER

The photograph provides opportunities for some interesting discussions. One of the biggest questions that can be asked is, “How old is the universe?” The scientific answer comes from the analysis of photographs such as this one. Since the discovery of the first galaxies over 80 years ago, scientists have been combining our understanding of the laws of nature with our observations of light from outer space. About 50 years ago, estimates of the universe’s age were between 10 to 20 billion years old. With information supplied by the Hubble Space Telescope and other new telescopes, the estimated age of the universe has been refined in the last 10 years to about 13.8 billion years old.

Another interesting fact is that if a beam of light were to start out on a journey across the universe, it would take at least 14 billion years to make it all the way, if things stayed as they currently are. However, we know that the universe is still expanding and doing so at an ever-increasing rate, faster than the speed of light. Therefore, a beam of light could never catch up to the expansion.

These interesting facts are sure to entice students to want to learn more about optics. Point out that all that we know about the universe has arisen from the following:

- curiosity toward looking at the universe and ourselves
- understanding how the properties of light, mirrors, and lenses can be put together to make optical systems
- realizing that greater scientific knowledge depends on the understanding and use of optical technology, and vice versa

GETTING STARTED, pp. 128–129

Using the Text

The photograph of the air show provides a good opportunity to lead a discussion about the properties of light and colour. After students have read the Getting Started section, have a class discussion about the different ways light has been used to make the air show effective. For example, the clouds released by the jets are made visible by reflected sunlight. Yet if the same sunlight is reflected from all of the clouds, how can the clouds have different colours? This observation could lead to questions about what kind of light makes up sunlight, and how different materials can absorb or reflect certain colours.

The use of radio transmissions by the air team to synchronize its display could be another topic of class discussion. Radio waves are a form of energy that is closely related to light. In fact, radio waves are part of the invisible spectrum of electromagnetic radiation, while light is part of the visible spectrum. The photograph of the laser light show suggests that we can produce light in many ways, and we can apply this knowledge to entertainment as well as to scientific research.

Other parts of the reading can be used to explore the uses of optical technologies, including cameras, binoculars, and eyeglasses. Although different in structure, each of these optical systems functions on the same basic properties of light and the characteristics of images produced by lenses. Our own vision depends on these principles. The anatomy of the human eye and how we see, including problems with focussing, will be discussed in the unit.

USING THE ACTIVITY

Find Out Activity

Light is Energy, p. 129

Purpose

- Students discover that light is energy, and demonstrate this finding in a concrete way using solar calculators.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Gather solar calculators or remind students to bring them from home for the day of the activity.	For each pair: – solar calculator witout a backup battery or with the battery disabled

Time Required

- 10 min

Science Background

Visible light is a form of energy, and energy can be used to perform work. There are two energy needs in the calculator—energy is needed to light the display and to perform and store the calculations. Removing light from the solar panel results in the calculator no longer being able to display numbers, and restoring the energy supply gets the display working again. The display takes the greater amount of energy, which means the calculator may be able to calculate and store information for a short time even though the display is non-functional.

Activity Notes

- Have students work in pairs.
- Note that energy is never destroyed, it is only transformed. In this activity, light energy is transformed into electrical energy.
- Ask students if they can figure out how to turn off the calculators. Many solar calculators do not have an "off" button.

Supporting Diverse Student Needs

- For enrichment, students could research the applications and functions of solar panels.

What Did You Find Out? Answers

1. When light was prevented from reaching the solar panel, the display faded out.
2. In most cases, the calculator was unable to retain the numbers that were entered before the solar panel was covered. The longer the solar panel is covered, the more likely it is that the entered numbers will be lost. Energy is required to maintain a number in the calculator's memory.
3. Students' answers could include the following: Energy is a measure of the ability to do work. For a solar calculator, energy is needed to keep the display on and make the calculator work. The light gives the calculator the energy it needs to do this.

CHAPTER 4 OPENER, pp. 130–131

USING THE PHOTO AND TEXT

The photograph of ripples in a pond that introduces this chapter is an opportunity to talk with students about the use of models in science. A model is a representation of a scientific idea or process that allows scientists to construct and test inferences and theories. It is an analogy, or a way of looking at something from a certain point of view.

In this chapter, two different models of light are described: the particle model of light, and the wave model of light. Early Greek philosophers used the particle model of light to explain how people were able to see objects. As scientists studied the properties of light more carefully, they made observations that could not be explained by the particle model of light, and began to realize that light behaved more like a wave than a stream of particles. This idea led to the development of the wave model of light.

Water waves and sound waves have some properties that are similar to the way light behaves. For example, all three carry energy. Ask students where and how they might have felt or seen the energy in a water wave (swimming, erosion). Similarly, ask where they have seen evidence that light carries energy. Results from the Find Out Activity in the Getting Started section can be used to establish that light does carry energy.

It is important to emphasize that no model is perfect. Some parts of the model will apply while others will not. For example, ask whether sound can travel through outer space. (No, because there is no medium. A sound wave needs to have something to travel through.) Ask students if they believe light can travel through outer space. How do they know? (Sunlight travels through outer space before it reaches Earth.)

USING THE WHAT YOU WILL LEARN / WHY IT IS IMPORTANT / SKILLS YOU WILL USE

Read the What You Will Learn points aloud with students and ask them to brainstorm answers to the following questions:

- How can you tell if something carries energy? What does it do?
- What example in nature shows us that light is made up of different colours?
- What are some examples of electromagnetic waves?

The answers can help you determine students' prior knowledge of light and its properties.

Use the Why It is Important and Skills You Will Use features to discuss how light is important in our everyday lives. Ask students about their experiences using optical devices such as cameras, binoculars, microscopes, and telescopes. Take this opportunity to discuss skills in observing and describing things using models. Review skills used in drawing and labelling diagrams by having a volunteer draw and label a diagram showing the important parts of binoculars or another optical device.

USING THE FOLDABLES™ FEATURE

Encourage students to complete this exercise as they read the chapter. The labels of the four-tab Foldable correspond to the headings of the four sections in this chapter. Students can use this Foldable to define new terms and to summarize key ideas for each section. See the Foldables section of this resource for additional information about this feature.

4.1 THE NATURE OF LIGHT

BACKGROUND INFORMATION

Early philosophers and scientists disagreed about whether light consisted of particles or waves. Beginning with Pythagoras in 580 B.C.E., up to the 1500s, scientists continued to accept the particle theory of light. In the 1600s, as scientists observed more properties of light, they found the particle model could not explain some of the observations, and the wave model of light was introduced by Christian Huygens and Robert Hooke. However, most scientists were still not convinced that light behaved as a wave, including Isaac Newton. It wasn't until the early 1800s that two scientists, Thomas Young and Augustin Fresnel, were able to provide conclusive evidence to support the wave model of light.

Newton's insistence that light was made of fast-moving particles fell into general disfavour during the 19th century, when further evidence suggested that light travelled in waves. During the early 20th century, Albert Einstein once again changed the way scientists thought about light. Einstein's studies suggested that perhaps Newton was correct in some ways after all. Current scientific thinking about light, although well beyond the grasp of Grade 8 students, is that light behaves like both waves and particles; the wave-particle duality theory.

The first person to measure the speed of light very accurately was Albert Michelson. He used a strong light source, an eight-sided wheel with mirrors on each side, and a large mirror about 35 km away from his measuring equipment. By aiming the light source at mirror #1, the light was reflected to the distant mirror where it bounced back to hit mirror #2, which had rotated into position to reflect the light into the telescope. Using the measurements for distance travelled, angle of reflection, and the speed of the rotating wheel, Michelson was able to calculate the speed of light to be 299 796 km/s.

Although it seems as if light travels instantaneously, light does have a finite speed. In a vacuum, the speed of light is 299 792.458 km/s, or approximately 300 000 km/s. Relatively speaking, the speed of light is very quick, but if we consider the incredible distances in the universe, it may not seem so fast after all. For example, light that reaches Earth during a sunrise or sunset actually left the sun eight minutes earlier. The speed of light depends on the medium (e.g., air, water, glass) through which the light is travelling; the denser the substance, the slower the speed of light.

COMMON MISCONCEPTIONS

- Some students may believe that models proposed by scientists are always true and accurate. Explain to students that a model is used by scientists to explain why things happen the way they do but scientists understand that the model they use may not perfectly represent the thing they are studying. As advancements in technology are made and more experiments are conducted, a better understanding of the topic develops and the original model may need to be changed or revised.
- Light does not occur instantaneously. When a light switch is turned on, it seems as though we see the light instantaneously due to the relative short distance between the light source and the observer. Since the speed of light is about 300 000 km/s, the time it takes for the light to reach our eyes is only a fraction of a microsecond.

ADVANCE PREPARATION

- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 132

Using the Text

The text introducing this section focuses on the different ways in which early philosophers and scientists believed light and vision worked. The different models presented are an indication of how scientists do not always agree with each other. Discuss with students how a difference in beliefs actually helps to develop further scientific understanding of a topic (e.g., sharing of ideas, experiments carried out to prove/disprove ideas, development of technology, new inventions).

Have students develop a flow chart to show the development of the first pair of spectacles (glasses), i.e., reading stone → magnifying lens → spectacles. Brainstorm a list of other optical inventions and discuss how they have changed over time.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-3 and 2-4, Chapter 4 Key Terms, can be used to assist students.

Using the Did You Know, p. 132

The Did You Know? on page 132 briefly describes some of the influential work of Ibn al-Haytham in the field of optics. Unlike the early Greek philosophers, al-Haytham performed controlled experiments to test his ideas, which allowed him to demonstrate and prove various properties of light, including reflection and refraction. His experimental approach led him to be considered by some as the pioneer of the modern scientific method. Review and discuss with students the importance of the scientific method.

TEACHING THE SECTION, pp. 133–136

Using Reading

Pre-reading—Predict-Read-Verify

Break up the section into manageable chunks for students. Some suggested chunks are the following:
- Models of Light
- Early Technologies Involving Light
- Speed of Light

Use the chunks as topic titles for discussion. Ask students to read the titles and look at the diagrams to make a prediction about what each chunk will be about. Upon reading the student textbook, ask students to compare or verify their predictions with what they learned.

During Reading—Note Taking

Encourage students to take notes as they read through each chunk. They can rewrite the topic titles in the form of questions to which they will find the answers as they read the section. For example, "What are the different models of light?" "What are some of the early technologies that involved light and lenses?" "Who invented them?"

Supporting Diverse Student Needs

- Remind Students that they can use the Reading Check questions to help them decide if they have missed any important information in their reading. Have them read each question and share their answer with a classmate. For any question that their partner thinks they have not answered fully, both students should look up the information they need to develop a full answer in the textbook.

After Reading—Reflect and Evaluate

Have students review their notes and choose three facts that they think represent interesting new ideas. They can then write a statement about why they found these to be interesting and propose further research they may conduct for future learning.

Reading Check Answers, p. 134

1. The early Greeks described light as being made up of tiny particles. Some philosophers believed that beams of light particles came from objects that reached the eye and carried information about the object. Other philosophers believed that the eyes sent out fibres of light that touched objects and told the eyes what the object looked like.
2. The first object that was used to help people read small print was called a reading stone. It was a section of a glass sphere with one flat side.
3. By experimenting with the shape of the lenses, Leeuwenhoek discovered that he could increase the magnifying power of a lens by increasing its curvature.
4. In the early 1600s, Galileo built and used the first telescope to magnify objects in space.
5. (a) One example of a technology that was developed before the science was understood is the use of lenses to improve and enhance vision. People began using lenses before scientists fully understood the properties of light.
   (b) One example of a technology that made scientific discoveries possible is the invention of the microscope. With a microscope, scientists made many discoveries of micro-

scopic living organisms and non-living things, which previously could not be seen with the naked eye. Another example of a technology that helped scientists make new discoveries is the development of the telescope. With the telescope, scientists were able to expand our knowledge of the universe.

Reading Check Answers, p. 136

1. As scientists began to study light more carefully, they discovered that some properties of light could be better explained if light behaved like a wave, rather than a stream of particles. For example, light spread out as it passed through narrow openings and bent a bit around corners.
2. Galileo's efforts to measure the speed of light were unsuccessful because in his experiment, the time it took to uncover the lanterns was greater than the time it took for the light to travel between the lanterns.
3. The first person to accurately measure the speed of light was Albert Michelson. The equipment he used in his experiment included a light source, an eight-sided wheel with mirrors on each side, and a large distant mirror.
4. The speed of light (approximately 300 000 km/s) is much faster than the speed of sound (343 m/s).

USING THE FEATURE

Using the Did You Know, p. 136

Use the Did You Know? feature on page 149 of the student textbook to revisit what students have already learned about the speed of light in Section 4.1, page 135. That is, although light is the fastest thing known, it is not instantaneous.

Discuss other points to ponder:

- The speed of light is incredibly fast. For example, astronauts took four days to fly to the Moon in the early 1970s. A laser beam can travel the same distance in just under 1.5 s. We know this fact because the astronauts placed a mirror on the Moon, and it is possible to shine a laser light off of it from Earth, and then detect the reflection. The round trip time is less than 3 s.
- The speed of light changes as it moves from the vacuum of space into the atmosphere of Earth. As light passes into denser materials such as glass, and ultimately the densest transparent material known, diamond, the light slows down even more.

SECTION 4.1 ASSESSMENT, p. 137

Check Your Understanding Answers

Checking Concepts

1. Some early Greek philosophers believed that beams of light, made up of tiny particles, travelled from an object to the eye, carrying information about the object. Others believed that the eyes sent out fibres of light that touched an object and gave the eyes information about the object.
2. A reading stone is a section of a glass sphere with one flat side. By placing the reading stone on a page, the print was magnified.
3. The first spectacles (glasses) were made by attaching two magnifying glasses together at the handles.
4. Leeuwenhoek improved the magnification of the microscope by increasing the curvature of the lens.
5. As more experiments were performed after the 1500s, scientists questioned the theory that light was made up of particles. Instead, some scientists began to believe that light behaved like a wave.
6. Galileo was the first person to try to measure the speed of light. Unfortunately, his experiment did not work. He also developed an early telescope.
7. The speed of light is 299 792.458 km/s (or approximately 300 000 km/s).
8. You can determine how far away a lightning strike is by measuring the time between seeing the lightning and hearing the thunder (in seconds), and multiplying that measurement by the speed of sound (343 m/s).

Understanding Key Ideas

9. People were able to make lenses and build telescopes and microscopes without fully understanding the nature of light by experimenting with the materials that were available.
10. It was difficult to measure the speed of light because the time it took light to travel a short distance was much too quick to be measured accurately.
11. Students may use a chart or Venn diagram to compare and contrast Leeuwenhoek's micro-

scope with modern microscopes. Students' answers could include the following:

LEEUWENHOEK'S MICROSCOPE	MODERN MICROSCOPE
– used the properties of light and lenses to magnify tiny objects – sample was placed on the point of the screw – contained a single convex lens found on the opposite side of the opening – magnified objects 200× larger	– uses properties of light and lenses to magnify tiny objects – sample is placed onto a slide which rests on top of the stage – contains more than one lens, located in the objective and eyepiece – magnifies objects up to 2000×

12. In his experiment, Galileo intended to calculate the speed of light by measuring the time it took for light to travel between two lanterns, and dividing that measurement by the total distance that the light travelled during that time. He was unsuccessful because the time it took to uncover the lanterns was greater than the time it took for the light to travel between the lanterns.
13. Scientists can measure the time it takes the laser beam to travel to the mirror and multiply this measurement by the speed of light to find the distance between the Earth and the Moon.

Pause and Reflect Answer

Students should treat this question as a Science-Math Connect and apply their mathematical and problem-solving skills to solve it.

First, students need to realize that the time must be converted from minutes to seconds since the speed of light is measured in metres per second:

Time = 8 min
= 8 min × 60 s/min
= 480 s

Second, students need to use the proper formula for distance, knowing the values for the speed of light and time taken:

distance = speed × time
= 3×10^8 m/s × 480 s
= 1440×10^8 m
= 1.44×10^{11} m

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

4.2 PROPERTIES OF WAVES

BACKGROUND INFORMATION

Light is a form of energy. The idea that light can be represented by a wave depends on the understanding that a wave is a disturbance that transfers energy, but not matter, through space. This understanding is true even for water waves. This idea may take some development, because the idea of surfing is based on using a wave to propel the surfer along with the wave. Also, students will have seen objects such as kayaks, branches, or lost objects moving in the direction of the waves. This occurrence is a result of the wind pushing the part of the object that is above the water. Here it is useful to speak about the parts of the model that apply and the parts that do not. When we compare light to a water wave, we are thinking of water waves that bob an object, such as a buoy, up and down. The bobbing motion caused by a wave is perpendicular to the motion of the wave, and does not cause water or an object in it to move along with the wave. Some aspects of water waves do not match light waves. For example, light waves do not need a material medium to exist in. They can exist in the vacuum of space.

Frequency is measured in vibrations per second. The unit for frequency is called the hertz (Hz) in honour of Heinrich Hertz (1857–1894), who was the first person to send and receive a radio signal. He did not capitalize on this technology, but instead used it to show the connection between light waves and other invisible kinds of waves.

COMMON MISCONCEPTIONS

- Some students may hold onto the idea that water moves along with a water wave based on real observations of surface waves that move over the top of a body of water and tides that move in and out of the shoreline. Explain that there are forces in nature that cause these water displacements such as the wind, the Earth's rotation, and the moon's gravitational pull on Earth. This is the case of choosing your analogy correctly, and emphasizing to students that we are only considering the bobbing motion of waves and not considering outside factors that may affect the motion of things in the waves. You may also try using the analogy of a wave formed by the fans at a sports game. The people move up and down in their seats, perpendicular to the movement of the wave across the stands.
- Be careful to stress that the height of the wave or amplitude is measured from the equilibrium point (rest position) to the crest or to the trough. The

difference in height between the crest and the trough is considered to be twice the amplitude.

ADVANCE PREPARATION

- For Find Out Activity 4-2A, Watching Water Waves, on page 138 of the student textbook, you will need pie plates or shallow pans.
- For Think About It Activity 4-2C, Catch a Waveform, on page 143 of the student textbook, you will need metre sticks, cardboard, and C clamps.
- For Conduct an Investigation 4-2D, Wire Waves, on pages 144 and 145 of the student textbook, you will need coiled metal springs.
- Consult the Unit front matter for a list of other BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 138

Using the Text

Have students read the text on page 138. Challenge them to describe a wave as they might experience it if they were the surfer in Figure 4.10. In which direction would they be moved by the wave? (up and down) How do microwaves work to cook food? (Microwave energy causes the water molecules in the food to vibrate and rub against each other. This friction produces heat that cooks the food.)

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-3 and 2-4, Chapter 4 Key Terms, can be used to assist students.

Using the Activity

Find Out Activity 4-2A

Watching Water Waves, p. 138

Purpose

- Students investigate the relationship between frequency and wavelength.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For each group: – pie plate – water – pencil

Time Required

- 15 min

Science Background

This very basic exploration gives students a chance to notice that as the frequency of the waves increases, the wavelength decreases.

Activity Notes

- Have students work in pairs or small groups. Alternatively, this activity could be completed as a teacher demonstration using a transparent pan and an overhead projector. The waves cast shadows that are visible on the screen.
- In addition to noting that increasing the frequency decreases the wavelength, students can note that increasing the frequency does nothing to increase the speed of the wave. The speed of the wave is constant for this medium and at this depth.

Supporting Diverse Student Needs

- Students with written output challenges could draw diagrams to answer What Did You Find Out? questions 1 and 2.
- As an extension, have students place a small piece of cork on the water and observe its motion as the waves move across the surface of the water. Then draw a series of waves on the board like the ones on page 139 (showing the trough, the crest, and other parts passing the same point), and have students describe the position of the cork in each diagram. (The cork should move almost completely up and down. It should not move along the surface with the crest of the wave.)

What Did You Find Out? Answers

1. Tapping the water with your pencil creates waves that travel outward in concentric circles.
2. The spacing of the water waves decreases as the rate of tapping increases.

TEACHING THE SECTION, pp. 139–142

Using Reading

Pre-reading—Predict-Read-Verify

Break the section up into manageable chunks for students. Some suggested chunks are the following:
- Features of a Wave
- A Water Wave Moves Energy, Not Water
- Two Types of Waves

Use the chunks as topic titles for discussion. Ask students to read the titles and look at the diagrams to make a prediction about what each chunk will be about. Upon reading the student textbook, ask students to compare or verify their predictions with what they learned.

During Reading—Note Taking

Encourage students to take notes as they read through each chunk. They can rewrite the topic titles in the form of questions to which they will find the answers as they read the section. For example, "What are the main features of a wave?" "What are the two types of waves?"

After Reading—Semantic Mapping

Have students review their notes and summarize them in two Venn diagrams—one to compare and contrast amplitude, frequency, and wavelength, and one to compare and contrast transverse and compression waves. Students can also use BLM 2-9, Riding the Waves to summarize what they have learned.

Supporting Diverse Student Needs

- Draw students' attention to Science Skill 10, Using Graphic Organizers, on page 486–487 of the textbook. It includes information about using Venn diagrams, as well as other graphic organizers that will help them illustrate connections in what they read.

Reading Check Answers, p. 142

1. A crest is the highest point of a wave and a trough is the lowest.
2. The three ways to measure wavelength are from crest to crest, trough to trough, or by picking any point on the wave and measuring the distance to the same place on the next wave.
3. The frequency of a wave is measured in hertz.
4. As the wavelength of a wave increases, the frequency decreases. This relationship is called an inverse relationship.
5. In a transverse wave, the matter moves perpendicular to the direction that the wave travels, while in a compression wave, the matter moves along the same direction that the wave travels.

USING THE ACTIVITIES

- Activity 4-2A on page 138 of the student textbook is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.
- Activity 4-2B on page 142 of the student textbook is best used after students have read and discussed the section on Frequency.
- Activity 4-2C on page 143 of the student textbook is best used after students have familiarized themselves with the features of a wave.
- Activity 4-2D on pages 144 and 145 of the student textbook is best used after students have been introduced to the difference between transverse and compression waves.
- Detailed notes on doing the activities follow.

Think About It Activity 4-2B

Frequency Formula, p. 142

Purpose

- Students practise using the formula for frequency.

Time Required

- 15 min

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Make copies of BLM 2-10, Frequency Formula (optional).	None

Science Background

The pendulum shown in the photograph has a regular period, which can be interpreted as frequency. The number of complete swings (returning to the starting point) in one second is called the frequency. The unit for swings per second (or vibrations or cycles per second) is the hertz (Hz) and is found by dividing the number of swings by the time in seconds. If the time is given in minutes, then this time must be multiplied by 60 s/min first.

Activity Notes

- Make students aware that 1 Hz is 1 cycle/s. For the frequency to be in hertz, the unit of time must be in seconds. If it is not, students need to convert it into seconds first (before using the formula).

- It may be helpful to practise converting minutes into seconds before beginning this activity.

Supporting Diverse Student Needs

- Work with a small group to guide mathematically challenged students in adapting the model in What to Do question 1. (a) to solve question 1. (b). They can make the calculations in question 1. (c), (d), and (e), on their own, and check their answers with a classmate.
- BLM 2-10, Frequency Formula provides scaffolding for the calculations in this activity.
- For enrichment, challenge students to come up with different frequency problems for one another to solve.

What To Do Answers

1. (a) $\frac{24 \text{ swings}}{6\text{s}} = 4 \text{ Hz}$

   (b) time = 2 min
   = 120 s;
   $\text{frequency} = \frac{12 \text{ revolutions}}{120\text{s}} = 0.1 \text{ Hz}$

   (c) time = 0.5 min
   = 30 s;
   $\text{frequency} = \frac{30 \text{ flashes}}{30 \text{ s}} = 1 \text{ Hz}$

   (d) $\text{frequency} = \frac{18 \text{ beats}}{20 \text{ s}} = 0.9 \text{ Hz}$

   (e) time = 1 min
   = 60 s;
   $\text{frequency} = \frac{2000 \text{ revolutions}}{60 \text{ s}} = 33.3 \text{ Hz}$

What Did You Find Out? Answers

1. In order to calculate frequency measured in hertz, the time unit must be converted to seconds before dividing.

Find Out Activity 4-2C

Catch a Waveform, p. 143

Purpose

- Students map a waveform using the motion of a vibrating metre stick.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For each group: – felt pen – metre stick – C clamp – cardboard or manila card stock (Have some spare pieces on hand.) – masking tape

Time Required

- 25 min

Safety Precautions

- Advise students to ensure the C clamp is properly secured, and not to hit the metre stick so hard as to break it or to cause it to fly off the desk.

Science Background

Any kind of regular vibration or repeating pattern can be used to generate a wave. Moving the cardboard against a vibrating pen is a way to get a permanent record of the vibration. It will yield a trace that can be measured to find the wavelength and the amplitude. By comparing the two traces, it will be possible to relate frequency to wavelength.

Activity Notes

- Have students work in pairs.
- Students need to keep a steady pace when walking with the cardboard against the vibrating pen; otherwise, the wave traced out will not be an accurate representation of the vibrating metre stick.
- Some students may experience difficulty getting a good trace on the first attempt. They should be encouraged to try the activity several times to discover how to get a good trace.

Supporting Diverse Student Needs

- If students have trouble either manipulating the metre stick or recording the waveform on cardboard, suggest that they switch roles and try the other job.
- Students could discuss their answers to the What Did You Find Out? questions. Once they agree on each answer, one partner could record it on paper.
- Listening to the different sounds produced by different wavelengths (when different lengths of the metre stick hang off the edge of the desk) and creating a pattern with them may be of interest to musical-rhythmic learners.
- As an extension, ask interested students to predict, then investigate what changes they will see in the wave when they press down more firmly on the metre stick, then release it.

What Did You Find Out? Answers

1. The sound of the vibrating metre stick changed when the amount of stick extending out from the desk was changed. The shorter length overhang vibrated with a louder volume and a higher pitch than the longer length overhang.
2. The longer length overhang produced waves with the longest wavelengths.
3. The shorter length overhang produced the most vibrations.
4. As the wavelength increases, the frequency decreases.
5. Increasing the wavelength decreases the frequency, and vice versa.
6. The wave with the greatest wavelength cannot have the greatest frequency because a greater wavelength means there must be fewer vibrations in the same time period.

Conduct an Investigation 4-2D

Wire Waves, pp. 144–145

Purpose

- Students use a coiled metal spring to investigate amplitude, wavelength, and frequency of a wave.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials. Make copies of BLM 2-11, Wire Waves (optional).	For each group: – coiled metal spring – piece of masking tape or string

Time Required

- 30 min

Safety Precautions

- Instruct students to not to let go of the spring when it is stretched out. A flying spring is very dangerous and could do damage to the body or another object in the room.
- Remind students that the end of the spring might be sharp. Students should take care not to be poked by it, or to catch the end on their clothing.

Science Background

Metal springs can be manipulated into making standing waves. In a standing wave, one or more parts of the spring stay in one place. This place is called a node. These kinds of waves are called transverse waves. Increasing the frequency by the correct amount can produce additional nodes, and at the same time, the wavelength will have decreased.

Activity Notes

- Students need to hold onto the spring carefully and not put too much tension on it.
- Putting a piece of tape or string on the spring helps to track the position of the spring as it moves from side to side.
- Students may be able to produce several nodes, which will be helpful in examining the relationship between frequency and wavelength.

Supporting Diverse Student Needs

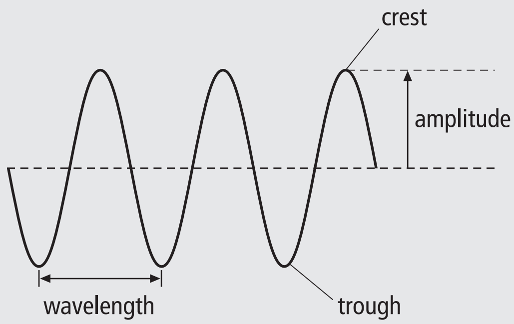
- Body-kinesthetic skills are required in this activity and logical-mathematical skills are needed for step 5 of the Procedure, the Analyze, and the Conclude and Apply sections. Ensure that pairs of students include learners with both skill sets.
- Students with written output difficulties can answer Analyze questions orally, or by demonstrating. You could also use oral Analyze answers as a check that students have understood the activity and are ready to complete Conclude and Apply.
- BLM 2-11, Wire Waves provides a template for recording results in this activity, for those students who would benefit from using one.
- For enrichment, students could model compression waves as described on page 141 of the student textbook.

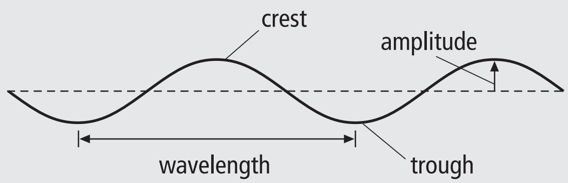
Analyze Answers

1. As the spring moved from side to side more quickly, the wavelength in the spring decreased.
2. The marked coil, which was in the middle, did not move from side to side. If it was at a node, students will say it did not move at all. If it was not at a node, students will say it moved up and down only.
3. (a) Frequency and amplitude are not related. However, students' experiences will vary and some students may find that to get high frequency, they tend to have high amplitude simply because they are working hard to move the spring back and forth.
   (b) A low frequency wave can sometimes have a high amplitude and other times have a low amplitude. It depends on how much side-to-side motion is used to generate the wave. More side-to-side motion means greater amplitude.

Conclude and Apply Answers

1. (a) and (b)





2. (a) As the frequency increases, the amount of energy transferred by the spring also increases.
   (b) As the wavelength increases, the amount of energy transferred by the spring decreases.

USING THE FEATURES

Using the Did You Know, p. 139

What properties of sound waves make them useful for forming an image? Like bats, which use echoes to sense their environment, ultrasound procedures use echoes to produce an image. The reflective properties of waves off different tissues and the speed of the waves through the body can be used to generate the image of an unborn child during an ultrasound procedure.

Sound waves also carry energy. High energy sound waves, which operate at frequencies much higher than ultrasound frequencies, can knock the debris off optical, dental, and surgical equipment. This result leads to the definition of a wave as a disturbance that transfers energy through matter or space.

www Science: Noise-Cancellation Headphones, p. 146

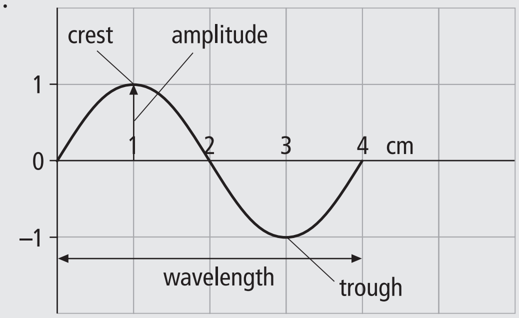
This feature is an excellent starting point for discussion or further research. In the near future, noise-cancellation headphones are likely to become very common. Have students read the feature together as a class. Ask whether any students are using these kinds of headphones. Brainstorm a list of possible uses for this type of technology not already mentioned in the feature (e.g., to block out the noise of a neighbour's lawnmower, to block out the drone of airplane engines while flying, for construction workers to block out the noise of a jackhammer).

SECTION 4.2 ASSESSMENT, p. 147

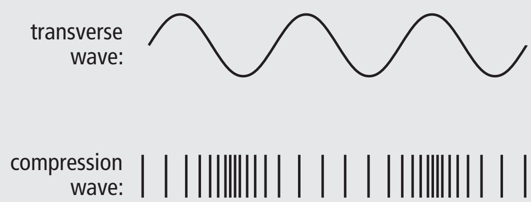
Check Your Understanding Answers

Checking Concepts

1.



2. (a) frequency = $\frac{900 \text{ times}}{1 \text{ s}}$ = 900 Hz
   (b) frequency = $\frac{880 \text{ times}}{2 \text{ s}}$ = 440 Hz
   (c) frequency = $\frac{10 \text{ times}}{50 \text{ s}}$ = 0.2 Hz
3. (a)



   (b) Students' answers could include the following: An example of a transverse wave is a water wave on the lake, or a coiled spring moving from side to side. An example of a compression wave is a sound wave moving through the air.
4. frequency = 0.5 Hz = 0.5 waves/s;
   number of waves in 8 s = 0.5 waves/s × 8 s = 4 waves

Understanding Key Ideas

5. (a) Recall the inverse relationship between wavelength and frequency. To make the wavelength shorter, you need to shake the rope more quickly.
   (b) To increase the energy carried by the wave, you need to either increase the amplitude by increasing the side-to-side motion, or increase the frequency by shaking the rope faster.
6. Water waves moving under a raft raise the raft higher and then lower as the crest and trough pass beneath it. The motion is perpendicular

to the direction of the waves, so the raft only moves up and down, and not horizontally.

7. (a) The distance between the crest of a wave and the trough of a wave is two times the amplitude. So, in this case, the crest will be 30 m above the trough.
   (b) 10 km = 10 000 m and 1 h = 60 min Therefore, one hundred 100 m waves will pass by in 60 min, or 10 waves will pass by every 6 min.
8. (a) Pendulum A: frequency $= \frac{32 \text{ swings}}{8 \text{ s}}$
   $= 4 \text{ Hz}$
   Pendulum B: frequency $= \frac{72 \text{ swings}}{9 \text{ s}}$
   $= 8 \text{ Hz}$
   Pendulum C: time = 1 min 20 s
   = 80 s;
   frequency $= \frac{210 \text{ swings}}{80 \text{ s}}$
   $= 2.6 \text{ Hz}$
   (b) From lowest to highest frequency: C, A, B
9. (a) The baritone singing a lower pitch produces waves of a longer wavelength. Lower pitch means lower frequency, which implies longer wavelength.
   (b) If both singers sing at an equal volume, the singer with the higher pitch sends out more energy. Every vibration sends out energy, and the higher pitch sends it more frequently (i.e., higher frequency).

Pause and Reflect Answer

Students' responses should include the following answer: A wave with a length of 6 cm and a frequency of 2 waves/s = 2 Hz will change when the frequency changes to 4 waves/s = 4 Hz. When the frequency doubles in value, the wavelength reduces by a half to become 3 cm.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

4.3 PROPERTIES OF VISIBLE LIGHT

BACKGROUND INFORMATION

The light that we can see is called visible light. All other types of energy waves (e.g., microwaves, infrared waves) are invisible to us. Visible light waves are composed of different colours of light, each with a different wavelength and energy. Red light has a longer wavelength and lower energy, while blue light has a shorter wavelength and higher energy. When all the colours are seen together, they make white light.

Refraction, or the bending of light as it moves between materials of different densities, can be explained using waves. In fact, water waves will refract as they approach a shore from an angle and begin to slow down and change direction in shallower water. The shorter the wavelength, the more the direction changes. A similar thing happens with light. The wave model can be used to understand how refraction forms rainbows. Figure 4.21 on page 150 shows how different colours of light refract by different amounts, leading to the formation of a spectrum of colours. For example, red light has a longer wavelength than blue light, so it refracts less than the blue light.

Since most objects do not produce their own light, the colour of the object that we see is really a reflection of the light in the room bouncing off the object. For example, a blue ball appears blue in the sunlight because the blue colour is reflected while the other colours are absorbed by the ball. Only the colours that are reflected are seen. In a dark room where there is no light source, the ball will appear black.

COMMON MISCONCEPTIONS

- Some students believe that a yellow shirt is yellow because it absorbs yellow light from the Sun, rather than yellow being the only colour that is actually reflected. You might ask students what colour light green plants absorb (colours other than green—mostly red). Then tell them that experiments have shown that plants grow best in red light, and do not grow well at all in green light. The plant has no use for green light, and reflects it. That is why it looks green.
- Some students may believe that colour is an intrinsic part of a material, rather than a property that exists only when the light is turned on. In other words, students do not understand that an object has no colour when there is no light falling on it. Explain that while we talk about a red shirt, or a blue bike, the colour names really tell us about the behaviour of light when it strikes each object.
- Students may confuse the three primary colours of light (red, green, and blue) with the three primary colours of paint/pigment (red, yellow, and blue). Refer them to Explore More on page 153 for more information on primary colours.

ADVANCE PREPARATION

- For Find Out Activity 4-3A, Rainbows of Light, on page 148 of the student textbook, flashlights,

glass prisms, and dishwashing liquid are needed for each group. You may want to gather these materials a day before completing the activity.
- For Find Out Activity 4-3B, Colour Your Rainbow, on page 153 of the student textbook, you will need a supply of old CDs; perhaps ask students one week in advance to bring in their own CDs.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 148

Using the Text

Have students read the text on page 148, which refers to a photograph of a rainbow. Lead a discussion on rainbows. Ask students to describe some of the rainbows they have seen (e.g., rainbows through stained glass windows, rainbows in oil spills, rainbows cast in the spray from a garden hose). Ask students, "What kinds of conditions are necessary for the formation of a rainbow?" (water droplets, the Sun behind the viewer) "What does this say about how rainbows form?" (The light reflects off the water droplets and bounces back to the viewer, but different colours bounce back differently.) An interesting feature of rainbow formation is that both refraction and reflection are involved (see Figure 4.21 on page 150).

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-3 and 2-4, Chapter 4 Key Terms, can be used to assist students.

Using the Activity

Find Out Activity 4-3A

Rainbows of Light, p. 148

Purpose

- Students examine rainbow effects created by a prism and soap bubbles.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials. Make copies of BLM 2-12, At the End of the Rainbow.	For each group: – flashlight – glass prism – water – dishwashing liquid – BLM 2-12, At the End of the Rainbow

Time Required

- 15 min

Safety Precautions

- Remind students to wipe up any spills immediately.

Science Background

This simple experiment allows students an opportunity to produce and examine a visible spectrum. Ask students how many colours they personally can see, and let them know to expect individual differences. For example, some students will not know or recognize the colour indigo. Be sensitive to the fact that 8% of males and 1% of females cannot distinguish red and green in the usual way.

The soap bubbles reflect a colour depending on the thickness of the bubble, since light reflects off both the front and back surfaces of the bubble. When the light bouncing off the back of the bubble mixes with the light bouncing off the front of the bubble, certain colours are reinforced, while others are cancelled out. To get a better idea of how this process works, students can reread the discussion on page 146, which talks about noise-cancellation headphones.

Activity Notes

- Have students work in pairs or small groups. Alternatively, this activity could be completed as a teacher demonstration.
- A strong flashlight is helpful.
- To provide students with additional experience investigating rainbows, assign BLM 2-12, At the End of the Rainbow as homework.

Supporting Diverse Student Needs

- Students could answer the What Did You Find Out? question as a write around. Have one student in each group begin, and pass the paper to others

to add their thoughts. Then, each student could choose one observation or conclusion to share with the class.
- For enrichment, challenge students to make bubbles with soap solutions of different concentrations to compare the colours that are seen. Alternatively, have students blow soap bubbles into the air and shine a flashlight on them to observe the reflection and refraction of the light.

What Did You Find Out? Answers

1. The glass prism may have produced a rainbow on the wall, with all the colours of the visible spectrum (ROY G BIV: red, orange, yellow, green, blue, indigo, and violet). The soap bubbles tend to show irregular ribbons of different colours of light. In both cases, the colours came out of the white light that was shone on the materials.

Using a Demonstration

Hang a decorative prism from a string near the window and allow sunlight to shine on it. (If there is no window in the classroom, shine a bright white light at the prism.) Spots of light should appear around the room, and these spots will move around as the piece of glass slowly twirls around. Most of the spots of light will have jagged edges, or fringes, of different colours—mini-rainbows. Ask students to think about the various things that are happening to the light as it encounters the piece of glass. See if students can spot reflection occurring. The place where the light passes through can be labelled as refraction. The fringes can be used to indicate the idea of a spectrum, as well as providing evidence that white sunlight is actually a composite of many different colours.

TEACHING THE SECTION, pp. 149–153

Using Reading

Pre-reading—K-W-L (Know-Want to Know-Learned)

Discuss with the class what they know about each of the Key Terms listed on page 148. Ask students to record their answers to the question, "What do I know about visible light and the spectrum?" Then, ask them to review their answers and record questions they have about visible light and the spectrum, for example, "Where does the spectrum come from?" and "What light is *not* visible?" Later, students can share their questions as a class and discuss the answers.

During Reading—Elaborative Interrogation

Tell students, if necessary, that the spectrums they created with soap bubbles were caused by refraction. Have them write one or more questions about how refraction might work to create a spectrum. Similarly, tell them that the colours we see on objects are really caused by reflection and have them write one or more questions about how that might work. They can take notes as they read to help them answer their questions.

Supporting Diverse Student Needs

- To help develop skills reading for information, after students have read this section, give each student an index card. Have each student write one question about reflection and one about refraction on the front of their card. On the back of their card, they should write the number of the textbook page on which each answer can be found. Students can exchange cards with a classmate and find the answer to each of their classmate's questions.

After Reading—Reflect and Evaluate

Have students review their notes and choose three facts that helped them answer one of their questions. They can then write a statement as to how the fact helped them answer their question and propose further research they may conduct for future learning.

Students can use BLM 2-13, ROY G BIV and BLM 2-14, Additive Primary Colours to summarize what they have learned. Students can extend what they have learned by using BLM 2-15, Sunrise, Sunset to explore the colours of sunrises and sunsets.

Reading Check Answers, p. 150

1. All the colours of the spectrum are present in white light. The different colours, each of which has a different wavelength, are refracted, or bent, by a different amount. The colours then exit the prism in different directions, producing the spectrum.
2. Red has the longest wavelength.
3. Violet has the shortest wavelength.
4. Violet has the highest frequency.
5. Red has the lowest frequency.

Reading Check Answers, p. 153

1. Newton observed that white light was split by the prism into different colours. He concluded that the colours were already present in the white light, rather than being produced by the prism, when he was able to rejoin the colours together with a second prism to produce white light.
2. A combination of any two of the three primary colours produces a secondary colour.

3. A green shirt looks green in white light because green is reflected and all other colours are absorbed.
4. A blue hat in a dark room looks black because there is no light to reflect off its surface. So no colour is generated and the hat looks black.

USING THE ACTIVITIES

- Activity 4-3A on page 148 of the student textbook is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.
- Activity 4-3B on page 153 of the student textbook is best used after students have read and discussed the Colour and Reflection section on page 152.
- Detailed notes on doing Activity 4-3B follow.

Find Out Activity 4-3B

Colour Your Rainbow, p. 153

Purpose

- Students investigate the effects of using different-coloured filters on the rainbow created by a CD.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Ask students to bring in old CDs.	For each group: – CD – coloured filters
1 day before	Gather materials. Make copies of BLM 2-15, What is Colour?	– coloured pencils or felt pens – white light source – BLM 2-15, What is Colour?

Time Required

- 20 min

Safety Precautions

- Remind students to never stare directly at the bright light.

Science Background

The filters will remove particular colours of light from the spectrum, which will then appear dark in those areas. For example, a red filter will remove (absorb) all colours except red. It does not matter to the viewer whether the light is filtered out before or after it strikes the CD.

Activity Notes

- Have students work in pairs or small groups. Remember that not all students are able to see every colour. It may be a good idea to label each filter paper.
- The best effects are obtained when a bright light source is used.
- For additional experience with coloured filters, have students do the activity on BLM 2-16, What is Colour?

Supporting Diverse Student Needs

- You may wish to provide students who have written output dificulties with sentence starters to help them write a paragraph in What Did You Find Out? question 2. Alternatively, you could show them how to create sentence starters themselves, using the words in the question. For example, to answer question 2, part (a), you might begin a sentence with, “When I look at the rainbow made from white light, … .” When a question asks them to explain, a good beginning might be, “This result occurs because … .” If some students are not able to write an effective paragraph, they could answer this question in point form.
- For enrichment, have students make a list of where coloured filters are used (photography, sunglasses, tinted windshields, spotlights used on stage). This task could lead to a small research project.

What Did You Find Out? Answers

1. Students may have seen various colours of the rainbow in their CDs. Filters let only one colour of light pass at a time.
2. (a) The rainbow made by the CD in white light contains most or all of red, orange, yellow, green, blue, indigo, and violet.
   (b) When a red filter is held in front of the rainbow, only the red appears to be present. The other parts simply appear dark.
   (c) It does not make any difference whether the filter is held between the CD and the eye or between the CD and the source because the filter removes light coming from the source, and it does not matter where this light was removed.
   (d) A coloured filter permits one colour to pass and absorbs the rest.

USING THE FEATURE

Career Connect: Concert Lighting Designer, p. 154

After reading the Career Connect, students could be asked to do the following:

- Answer the questions (answers are provided below).
- Research to find out more about how concert lighting works.
- Create their own plans for stage lighting using BLM 2-17, Setting the Stage.

Career Connect Answers

1. The lights for a concert, each with different lenses and prisms, are integrated into one automated unit that is controlled by a central board. The board is equipped with a computer that has been programmed to move the lights and adjust the position, colour, intensity, and focus of the lights automatically.
2. The designer needs to understand how different lenses and prisms work in order to focus and direct the light and create patterns to achieve a desired effect.
3. If you wanted to become a lighting designer, you would need to be able to position lights around the stage as well as light the stage correctly. This process is planned and carried out using a computer. Using a computer-aided design program will help to produce good designs for both of these tasks.

SECTION 4.3 ASSESSMENT, p. 155

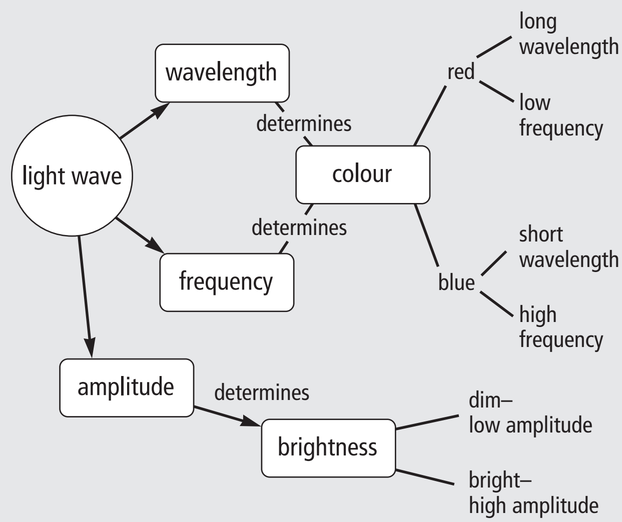
Check Your Understanding Answers

Checking Concepts

1. (a) A model is a way of representing something in order to understand it better and to make predictions.
   (b) According to the wave model, light is a type of wave that travels through empty space and transfers energy from one place to another.
2. Red light has a longer wavelength than green light.
3. Blue light refracts more in a prism than yellow light.
4. Sunlight contains all the colours of the rainbow. Each colour has a different wavelength, and the prism bends, or refracts, each colour by a different amount. This phenomenon causes the colours to emerge from the prism in slightly different directions, producing the spectrum.
5. Refraction is the bending or changing direction of a wave as it passes from one material to another. Reflection occurs when a light wave strikes an object and bounces off.
6. (a) A minimum of three coloured lights are needed to produce all possible colours, including white.
   (b) White light can be produced by combining red, green, and blue. It can also be produced by combining yellow, cyan, and magenta.
7. In the acronym ROY G BIV, the B stands for blue and the V stands for violet.

Understanding Key Ideas

8. (a) Red light is the colour that passes through the red filter.
   (b) Green light is absorbed by the red filter.
9. A shirt can look green even though the light falling on it contains red, blue, and green because the red and blue colours are absorbed, while the green is reflected.
10. The particles of water left in the air from the rain refract the white light from the Sun and separate it into the spectrum.
11. Student's answers may vary. Sample concept map:



12. (a) Light with a wavelength of 200 nm is in the region lower than violet and is invisible to humans.
    (b) 1 nanometre = 0.000 000 001 metres
    (i) 200 nm = 0.2 micrometres (ii) 200 nm = 0.000 2 millimetres (iii) 200 nm = 0.000 000 2 metres
13. (a) Sound representing red light will be one octave lower in pitch than middle C.
    (b) Green will be higher than middle C (yellow) but lower than C in the next octave up (blue). Orange will be lower than middle C (yellow) but not as low as red. Violet will be two octaves higher than C above middle C (blue).

Pause and Reflect Answer

Many artists prefer to blend their own green paints because the colours are more interesting to look at than a green paint made of only one green pigment.

The blending allows for many different shades of green, and also different kinds of light react differently to the blended greens, again leading to different qualities and moods in the paint.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

4.4 LIGHT AND THE ELECTROMAGNETIC SPECTRUM

BACKGROUND INFORMATION

Visible light is a tiny part of the electromagnetic spectrum (or the range of wavelengths that transmit radiant energy). The invisible part of the electromagnetic spectrum can be divided into wavelengths that are longer (and have lower energy) than visible light, as well as wavelengths that are shorter (and have higher energy).

In order of decreasing wavelength, the electromagnetic spectrum consists of radio waves, microwaves, infrared waves, visible light, ultraviolet light, X rays, and gamma rays. As shown in Figure 4.28 on page 158, visible light is only a very small part of the electromagnetic spectrum. Notice that all other categories of electromagnetic waves overlap. Often, identical electromagnetic waves can be produced in completely different ways and therefore can fit into more than one category.

A number of uses are given in the student textbook for waves in each region of the invisible spectrum. A particular emphasis in the student textbook is on the formation of images using each part of the spectrum. For example, radio waves are used in MRI imaging of a human brain; radar (shorter wavelength microwaves) produces maps of Earth; and an infrared image of a cat's face is given. On the other side of the visible region, an ultraviolet image of the Sun is shown, as well as an X ray of a hand by the man who discovered X rays. This theme fits in well with the general idea of optics, which deals strongly with the formation of images.

COMMON MISCONCEPTIONS

- Some students might believe that light is not a type of electromagnetic radiation since it is visible, while the other types of energy waves are invisible. Explain that electromagnetic radiation includes any kind of transmission of energy in the form of waves. Students will learn more about each type of electromagnetic wave on pages 158 to 164 of the student textbook.

ADVANCE PREPARATION

- For Find Out Activity 4-4A, Seeing the Invisible, on page 157 of the student textbook, and Find Out Activity 4-4C, Sunscreen Circles, on page 165, you will need a black light and sunscreen.
- For Find Out Activity 4-4B, Reflection in the Infrared, on page 165 of the student textbook, you will need a television set with a remote control and access to a refrigerator or freezer to complete the activity.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, pp. 156–157

Using the Text

Ask a student to write these Key Terms across the top of a page: radio waves, microwaves, infrared waves, ultraviolet waves, X rays, gamma rays. Then, as students read the text on page 156, create a list on the board of each example of electromagnetic radiation mentioned. Have students organize each example under the type of electromagnetic radiation they believe it represents. Have students revisit their answers as they read through the rest of the section, as well as add to the existing examples with some of their own.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-3 and 2-4, Chapter 4 Key Terms, can be used to assist students.

Using the Did You Know, p. 156

Physical sunscreens are often referred to as sunblocks. These products contain either zinc oxide or titanium dioxide, which physically block UV rays from penetrating the skin. The most common physical sunscreen is zinc block, made of zinc oxide, which is a bright white powder. The white colour indicates that it reflects visible rays as well as UV rays. Zinc block is often used by people with sensitive skin who find the chemicals used in other sunblock lotions to be irritating. However, it is harder to remove from the skin than chemical sunscreens.

Chemical sunscreens are often colourless and form a thin film on the skin. They usually allow visible light to pass through, but contain chemicals that absorb UV light. Students get a chance to see this effect clearly when doing Find Out Activity 4-4A, Seeing the Invisible, on page 157 of the student textbook.

Using the Activity

Find Out Activity 4-4A

Seeing the Invisible, p. 157

Purpose

- Students observe evidence of ultraviolet light and discover how sunscreen can block the UV rays.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 days before	Gather materials.	For each group: – beaker – tonic water – black light – SPF 30 sunscreen – Canadian currency bill

Time Required

- 25 min

Safety Precautions

- Remind students to never look directly at the black light.

Science Background

A black light is a light that produces most of its radiation in the ultraviolet (UV) range, which, being invisible to humans, makes the light appear dark. Some light is released in the blue and violet part of the visible spectrum, so the light does have some glow. Because of the UV energy that is released, you should not look directly at the black light from a close range for an extended period.

Some chemicals are able to absorb UV light energy and then release it immediately at a slightly longer wavelength—in the visible spectrum—which makes this energy visible. Many chemicals can do this, including some in body fluids and in the quinine found in tonic water. Forensics specialists can look for trace amounts of blood, mucus, or semen by shining a black light on an object. The body fluids will glow, or fluoresce. The method is very sensitive. It is even possible to detect dried blood on a wall that has been painted over this way.

As a security measure against counterfeiting, the Bank of Canada has UV security features built into their currency bills. When black light is shone on them, pictures, words, and spots in several colours will immediately appear. These are totally invisible in regular light, and photocopies of the bills will not produce this effect. All new bank cheques also have UV security features. It is very interesting to hold a cheque up to a black light.

Activity Notes

- Since this activity is found at the beginning of the section, some students may be unfamiliar with the term “UV light.” They will learn more about it later on, but for now you may wish to explain that this is light from beyond the violet end of the visible spectrum, and that too much UV light can cause sunburns.
- Sunscreen in a spray form may be more convenient in this lab than a lotion.

Supporting Diverse Student Needs

- Instead of writing answers to What Did You Find Out? questions 3 and 4, students could think about their own answers, then share them in a small group. Groups’ answers could be recorded by one group member once everyone in the group was in agreement.
- For enrichment, ask students to devise a way to use the results of this lab to produce and then read invisible messages. You may also challenge students to think of a way to determine whether someone has correctly applied sunscreen to his or her skin.

What Did You Find Out? Answers

1. Under normal light, tonic water is either colourless or has a slightly yellow tinge to it. Under black light, it has a blue/purple glow.
2. (a) When the beaker was covered with sunscreen, the tonic water no longer glowed.
   (b) The sunscreen absorbs UV light from the black light. The UV light is what causes tonic water to glow.
3. Tanning lotion that did not include sunscreen would not be able to block out UV light, and the tonic water would glow blue.
4. A colour photocopy of a currency bill would not have the UV sensitive pigments in it, and would not glow under a black light, as a regular currency bill does.

Using a Demonstration

You can demonstrate evidence of infrared rays by pointing a remote control at a video camera (or digital camera) that is connected to a television. Video cameras are sensitive enough in the infrared region to pick up the infrared light, or "glow," from the remote control. This infrared light appears on the television set as a white light.

TEACHING THE SECTION, pp. 157–164

Using Reading

Pre-reading—Predict-Read-Verify

Break up the section into manageable chunks for students. Some suggested chunks are the following:
Wavelengths Longer than Visible Light
- Radio Waves
- Microwaves
- Infrared Waves

Wavelengths Shorter than Visible Light
- Ultraviolet Waves
- X Rays
- Gamma Rays

Use the chunks as topic titles for discussion. Ask students to read the titles and look at the diagrams to make a prediction about what each chunk will be about. Upon reading the student textbook, ask students to compare or verify their predictions with what they learned.

During Reading—Note Taking

Encourage students to take notes as they read through each chunk. They can rewrite the topic titles in the form of questions to which they will find the answers as they read the section. For example, "What are ultraviolet waves and what are some uses of this type of radiation?" Have students connect ideas in the text with the photographs.

Supporting Diverse Student Needs

- Notes about this section can be created as a write-around. In groups of seven, each student can write about one type of electromagnetic radiation. Then students can pass their notes to another group member, who will refer to the textbook to add to, or refine, the notes as possible. At the end, provide an opportunity for each student to contribute something from their group's notes in a class discussion. Summarize, or have a student summarize, the results of the discussion on a class chart.

After Reading—Reflect and Evaluate

Have students review their notes and choose three facts that they find most interesting. They can then write a statement as to why they found these facts to be interesting and propose further research they may conduct for future learning. Students can extend what they have read by using BLM 2-18, Thermograms to find out more about how thermograms are used.

Reading Check Answers, p. 161

1. Visible light is found between infrared waves and ultraviolet waves on the electromagnetic spectrum.
2. Radio waves have the longest wavelength in the electromagnetic spectrum.
3. Microwave radiation in a microwave oven causes water molecules to absorb energy and heat up. A plate does not contain much water and the microwaves do not interact with it.
4. Radar can be used to track the location and speed of moving automobiles, aircraft, watercraft, and spacecraft. It can also be used in weather forecasting, where radar stations mounted on satellites are used to plot the position of clouds and show the location and intensity of precipitation and the speed of the wind.
5. Another term for heat radiation is infrared radiation.

Reading Check Answers, p. 164

1. Ultraviolet waves, X rays, and gamma rays have wavelengths shorter than visible light.
2. Ultraviolet waves enable the body to make vitamin D. They are also used by police detectives to study fingerprints. Another use for ultraviolet waves is to kill bacteria in food, water, and medical supplies.
3. Overexposure to ultraviolet waves can result in sunburns, skin cancers, and damage to the surface of the eye.
4. X rays are used to photograph teeth and bones, scan luggage at airport security, and to inspect for cracks inside jet engines without taking the engine apart.
5. Gamma rays are used in radiation therapy to kill cancer cells.

USING THE ACTIVITIES

- Activity 4-4A on page 157 of the student textbook is best used as an introductory activity. Detailed notes about this activity can be found in Introducing the Section.
- Activity 4-4B on page 165 of the student textbook is best used after students have read and discussed the section on infrared radiation. Since this activity requires students to take turns using the television

and remote control, it may be done at the same time as Activity 4-4C.
- Activity 4-4C on page 165 of the student textbook is best used after students have read and discussed the section on ultraviolet radiation. You may also direct students to revisit their observations in Activity 4-4A, Seeing the Invisible, on page 157 of the student textbook, and compare them to their results in this activity.
- Detailed notes on doing the activities follow.

Find Out Activity 4-4B

Reflection in the Infrared, p. 165

Purpose
- Students investigate the kinds of materials that reflect infrared light.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 days before Day of instruction	Gather materials. Obtain access to a television with remote control, and a freezer.	For each group: – television set with remote control – variety of materials such as cardboard, aluminum foil, paper, glass, cloth, mirror – freezer

Time Required
- 25 min

Science Background

A television remote control uses infrared rays to transmit a signal to the television set. Infrared remote controls have been around for 25 years, but do have limitations related to the nature of infrared light. For example, infrared remote controls have a range of only about 10 meters and require line-of-sight. These limitations mean the infrared signal will not transmit through walls and around corners; it needs a straight, unobstructed line to the receiving device.

Infrared light reflects just as visible light does, and a wide variety of objects will be successful at reflecting the beam coming from the remote.

Activity Notes
- Have students work in small groups. Alternatively, this activity could be completed as a teacher demonstration.
- Since students will have to wait for a turn to use the equipment, it might work to complete Activity 4-4C at the same time.
- If possible, keep a second set of materials in the freezer for each group to use and replace. Doing so will save the time that each group would use to cool the materials.

Supporting Diverse Student Needs
- Students could answer What Did You Find Out? question 1 by sorting the actual objects into two groups, instead of recording in writing.
- For enrichment, challenge students to design and conduct an experiment which answers the question: "Does the strength of the infrared signal weaken as more and more reflective surfaces are used between the remote control and the television?"

What Did You Find Out? Answers

1. (a) Most smooth objects will reflect the infrared beam. Aluminum foil, mirror, paper, and cardboard will reflect well.
   (b) Cloth will not reflect particularly well.
2. Students' answers will vary depending on materials cooled. The effect of cooling will not be systematic. Mirrors and aluminum foil are likely to still reflect infrared, though there may be some diminished ability.
3. Students' answers will depend on results. Ice will tend to absorb infrared light. However, it may also have some reflective capacity as the infrared beam bounces off its smooth surface.

Find Out Activity 4-4C

Sunscreen Circles, p. 165

Purpose
- Students will model how sunscreen protects skin from UV radiation.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 days before	Gather materials.	For each group: – paper – yellow felt pen – yellow highlighter – vegetable oil – SPF 30 sunscreen – black light

Time Required
- 30 min

Science Background

Highlighter pens appear bright because they absorb some light from the UV part of the spectrum and re-emit it in the visible spectrum. Vegetable oil will do nothing to block the UV action, but SPF 30 sunscreen will completely block the UV rays and the highlighter will lose its "bright" look and resemble an ordinary felt pen more.

Activity Notes
- Have students work with a partner.

- The effect of sunscreen on the highlighter is visible in normal light, but it is more pronounced when illuminated by a black light.

Supporting Diverse Student Needs

- Although this activity is relatively simple, the instructions may be difficult for some students to follow. Pair students who have trouble following written instructions with others who do not, or demonstrate how to prepare the circles before groups begin, to ensure that instructions are understood.
- For enrichment, have students experiment with gel pens, if available. Gel pens were first marketed in Japan in 1984. The ink inside gel pens is thicker than the ink found in standard ballpoint pens. As gel pens became more popular, companies began to produce them with fluorescent chemicals and metallic sparkles, which led to interesting light effects, especially when used on black backgrounds.

What Did You Find Out? Answers

1. Two of the circles made with a highlighter glowed under the black light.
2. The circles made with the highlighter only and the highlighter treated with oil both glowed, while the circle made with the highlighter treated with sunscreen did not.
3. Two circles were left untreated as a control.
4. Oil was also a control, showing that something in the sunscreen besides the oil caused the light absorption.
5. A regular pen and highlighter pen were both used because the regular pen was a control. This method showed that it was something in the highlighter ink that was affected by the black light.

USING THE FEATURE

www Science: Is Electromagnetic Radiation Helpful or Harmful?, p. 166

This feature is an excellent starting point for discussion, debate, or further research. The controversy over whether electromagnetic radiation is helpful or harmful has been going on for years, both in the scientific community as well as in the public domain. Have students read the feature together as a class. Then, ask them to draw up a chart listing the pros and cons of the different types of electromagnetic radiation mentioned in the feature. A research project could involve students looking for current (within the past 5 years) newspaper articles that relate to the benefits and/or risks associated with the use of electromagnetic radiation.

SECTION 4.4 ASSESSMENT, p. 167

Check Your Understanding Answers

Checking Concepts

1. (a) Radio waves, microwaves, and infrared waves have wavelengths longer than those of visible light.
   (b) Students' answers could include the following:
   radio waves: radio and television broadcasting, MRI imaging
   microwaves: microwave ovens, satellite communications
   infrared waves: remote controls, heating lamps
2. (a) Ultraviolet waves, X rays, and gamma rays have wavelengths shorter than those of visible light.
   (b) Students' answers could include the following:
   UV waves: production of vitamin D, forensics investigations
   X rays: medical imaging, airport security scanning machines
   gamma rays: treatment of cancer
3. Sunscreen and a hat protect the wearer from overexposure to UV waves, which cause premature aging of the skin, wrinkles, and skin cancer.
4. (a) Radiant energy is energy that can travel through the vacuum of space.
   (b) Students' answers could include any part of the electromagnetic spectrum, including visible light.
5. Radar can be used to help predict weather by mapping the formation and movement of weather systems. Weather radar devices convert the radio waves into pictures that show the location and intensity of precipitation and the speed of the wind.
6. X rays can be used for dental imaging, and other medical imaging such as soft tissues (breast cancer screening), as well as hard tissues (broken bones). They are also used to examine carry-on and stowed luggage in aircraft, as well as for examining hard-to-access locations such as aircraft engines and inside welds.
7. An MRI makes use of radio waves in forming an image of a person's internal tissues. The person is placed inside a very strong magnetic field. The atoms that make up a person's tissues behave like tiny magnets. Adding radio energy can cause the magnets to flip, which

releases radio waves that can be detected and used to create a map of the different tissues.

8. Microwaves carry energy that can easily be absorbed by water, though not by ceramic. For this reason, a mug will warm up more slowly than the water in it.

Understanding Key Ideas

9. Our eyes have evolved to be able to detect certain parts of the electromagnetic spectrum. The energy in visible light interacts with the pigments in our eye. Other energies, even more energetic ones, do not affect these light-collecting pigments.
10. (a) TV broadcast signals use radio waves.
    (b) A broken arm is detected with X rays.
    (c) The inside of a weld in a pipe is examined using X rays.
    (d) A lamp used to warm a baby chick uses infrared waves.
    (e) The speed of a passing car is measured with radar, a form of microwaves (which are a form of radio waves).
    (f) An aircraft and a control tower communicate using radio waves.
    (g) Cell phones use microwaves (which are a form of radio waves).
11. (a) A beneficial effect of human exposure to ultraviolet rays is the production of vitamin D in the body, which is needed for healthy bones and teeth.
    (b) The harmful effects of human exposure to ultraviolet rays are sunburn, skin cancers, and damage to the surface of the eye.
12. (a) An oncologist would likely use gamma rays to try to kill cancer cells in a patient.
    (b) Students' answers could include the following: The only part of the body to receive a continuous exposure to the gamma rays is the part identified as being made up of cancer cells. The person is constantly moved while undergoing therapy so that the gamma rays shine on the targeted cells from different angles.

Pause and Reflect Answer

Students' answers could include the following: Infrared photography could be used to show that a house may be poorly insulated and radiate an excessive amount of heat. Emergency response teams may use infrared devices to find people inside a house that has been damaged by an earthquake or a fire. Police may use infrared measurements to detect the presence of an illegal marijuana grow operation, or to locate suspects and/or hostages inside the house.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

CHAPTER 4 ASSESSMENT, pp. 168–169

PREPARE YOUR OWN SUMMARY

Students' summaries should incorporate the following main ideas:

1. Early Ideas About Light
   - Early Greek philosophers believed that light was made up of tiny particles.
   - Before scientists understood the nature of light, they made lenses and spectacles (glasses), and built simple microscopes and telescopes.
   - As more experiments were conducted, scientists made observations that could not be explained by the particle model of light, so the wave model of light was introduced.
2. Features of Waves
   - All waves are disturbances that result in the movement of energy from one place to another.
   - Waves are characterized by wavelength, amplitude, and frequency. As the wavelength increases, the frequency decreases.
   - There are two types of waves: transverse waves and compression waves. In a transverse wave, matter in the medium moves perpendicular to the direction that the wave travels. In a compression wave, matter in the medium moves back and forth along the same direction that the wave travels.
3. The Visible Spectrum
   - White light contains a mixture of all the colours of the rainbow.
   - ROY G BIV identifies the colours of the rainbow, in order, as red, orange, yellow, green, blue, indigo, and violet.
   - A prism can be used to split sunlight into the visible spectrum, which can then be recombined into white light using a second prism.
4. Reflection and Refraction
   - Reflection occurs when a light wave strikes an object and bounces off its surface.
   - Refraction is the bending or changing direction of a wave as it passes from one material to another.
   - The amount that a wave refracts, or bends, depends on its wavelength. Longer wavelengths refract less than shorter wavelengths.

5. Benefits and Risks of Using Electromagnetic Radiation
   - Electromagnetic radiation is the transmission of energy in the form of waves.
   - The electromagnetic spectrum consists of (in order of decreasing wavelength): radio waves, microwaves, infrared waves, visible light, ultraviolet waves, X rays, and gamma rays.
   - Each type of electromagnetic radiation has benefits and risks associated with its use.

CHAPTER REVIEW ANSWERS

Checking Concepts

1. Pythagoras was a Greek philosopher who was born around 580 B.C.E. He believed that beams of light (made up of tiny particles) came from objects and reached the eye, carrying information about the object.
2. Students' answers could include a description of lenses used to make magnifying glasses, the first pair of spectacles, or simple microscopes and telescopes. (Refer to pages 133–134 of the student textbook for details and photographs of each early technology.)
3. Although many scientists supported the wave theory of light, the first people to provide conclusive evidence of the model were Thomas Young and Augustin Fresnel in the early 1800s.
4. (a) F: crest
   (b) G: amplitude
   (c) H: trough
   (d) J: wavelength
5. As wavelength increases, frequency decreases, and vice versa. Another way to say this fact is that they are inversely related.
6. Light waves and sound waves both carry energy. Their waves both can be characterized by frequency, wavelength, and amplitude.
7. Students' answers could include the following: One way to measure the wavelength of a small water wave is to hold a ruler over the top and sight two wave crests at the same instant along the ruler.
8. (a) All colours of light have waves with the same general shape as that of a transverse wave. Also, the light waves move at the same speed in a vacuum, regardless of colour.
   (b) Different colours of light have waves with different wavelengths and frequencies.
9. Hertz (Hz) is the unit used to measure frequency. 1 hertz means one vibration or cycle per second.
10. Wavelength measures the distance from crest to crest, or trough to trough (or any place on a wave to the same place on the next wave). Wave amplitude measures the distance from the crest (or trough) to the equilibrium position, which in a water wave is the position of the surface of the water when there is no wave.
11. (a) The amplitude of Wave A is 0.5 m.
    (b) The wavelength of Wave A is 1.0 m.
12. (a) The amplitude of Wave B is 0.4 m.
    (b) The wavelength of Wave B is 2.1 m.
13. (a) The amplitude of Wave C is 0.6 m.
    (b) The wavelength of Wave C is 2.0 m.
14. A shirt can appear blue in white light because the pigment in the blue shirt absorbs non-blue colours such as red and green, while at the same time reflecting blue.
15. Radio waves and infrared waves have waves that are longer than visible light, while ultraviolet waves, X rays, and gamma rays have waves that are shorter than visible light.
16. Radio waves are used in MRI technology to form an image of soft tissues such as those in the brain. The person is placed in a very strong magnetic field. The atoms that make up the tissue behave like little magnets. When stimulated with a small amount of radio waves, the magnets can flip. This action causes a radio signal to be released, which is detected by the MRI machine. These signals represent information about the tissues that can be converted into pictures.

Understanding Key Ideas

17. Students' answers could include the following: Early philosophers and scientists always include vision in their ideas bout the nature of light because the eyes are able to see objects in the presence of light. Vision is our only sense that detects light. A person's vision is limited in the darkness, and darkness is sometimes even associated with blindness.
18. Lightning and thunder occur at the same time. However, you see lightning before you hear the thunder because the speed of light (about 300 000 km/s) is much faster than the speed of sound (342 m/s).
19. Light waves and waves in a fish pond are both disturbances that carry energy. They can both be characterized by wavelength, amplitude, and frequency.

20. (a) frequency $= \frac{14 \text{ crests}}{7 \text{ s}}$

$= 2 \text{ Hz}$

(b) frequency $= \frac{30 \text{ crests}}{5 \text{ s}}$

$= 6 \text{ Hz}$

(c) frequency $= \frac{0.5 \text{ crest}}{10 \text{ s}}$

$= 0.05 \text{ Hz}$

21. Wavelength and frequency cannot both increase together because as the wavelength gets longer, the troughs and crests get farther and farther apart. This result means that the frequency must decrease rather than increase.
22. Students' answers could include the following:

RADIATION TYPE	DIFFERENCES	SIMILARITIES
Infrared waves	– lowest frequency and energy of the three types of radiation – invisible to the human eye	– All three types of radiation move in the form of waves. – All three types of radiation move at the same speed. – All three types of radiation carry energy.
Visible light	– intermediate frequency and energy of the three types of radiation – visible to the human eye	
X rays	– highest frequency and energy of the three types of radiation – can pass through humans – invisible to the human eye	

23. (a) The red light has the longest wavelength.
    (b) The violet (or blue, if that is what she sees) has the highest frequency.
    (c) If Mei Lin were to remove the middle colours of the spectrum, leaving only red and blue, then the colour she would see when these are recombined is magenta.
24. Students' answers could include: X rays cause cancer if received in too great a dosage. A huge overexposure could even cause burns or other direct damage to tissues.

Pause and Reflect Answer

Gamma rays can be used in the treatment of cancer. They are high frequency waves that carry a large amount of energy, which can kill living cells. If you know the exact location of the cancer cells, you could hit them with a continuous dose of the deadly rays from different angles to kill all the targeted cells.

CHAPTER 5 OPENER, pp. 170–171

USING THE PHOTO AND TEXT

The photograph of the scenery reflected in the lake can be used to trigger students' memories of the different surfaces in which they have seen their reflections. Ask, "Where have you seen your reflection? What type of surface produces the clearest image?" Use students' responses as a lead in to a discussion about the different types of material that objects are made of, and how light hitting the objects' surfaces may respond (transmit, reflect, absorb).

A key topic in this chapter is the law of reflection. Students investigate this law by drawing ray diagrams, and describing the characteristics of images produced in plane, concave, and convex mirrors. Have students analyze the reflection in the picture of the lake more carefully. What do they notice about the images cast compared to the objects themselves? (same size, same apparent distance from surface of the lake) Ask, "Are these characteristics true for all types of mirrors?" (No, funhouse mirrors, for example, produce images that are distorted.) Different types of mirrors are used for different purposes because of the different types of images they can produce.

USING THE WHAT YOU WILL LEARN / WHY IT IS IMPORTANT / SKILLS YOU WILL USE

Read the What You Will Learn section aloud with students and ask them to brainstorm answers to the following questions:

- What is reflection? What do you think is "the law of reflection"?
- What is the difference between plane, concave, and convex mirrors? How do they affect your image?
- Where are mirrors used in your daily lives? What type of mirrors are they?

The answers can help you determine students' prior knowledge of light and its properties.

Use the Why It Is Important and Skills You Will Use features to discuss how reflection and the use of different kinds of mirrors are important in students' everyday lives. Besides describing and observing, students will have an opportunity to investigate, discover, explain, measure, and model different ways in which light, mirrors, and lenses work. Before engaging in the activities, you may decide to review their skills in drawing and labelling diagrams. Some conventions of scientific drawing are presented in Science Skill 3, page 476.

USING THE FOLDABLES™ FEATURE

Encourage students to complete this exercise as they read the chapter. The labels of the six-tab Foldable cover various aspects of reflection, images, and mirrors. Students can use this Foldable to define new terms and to summarize key ideas for each topic. If students use graph paper to make the Foldable, they can include ray diagrams for the different types of mirrors. See the Foldables section of this resource for additional information about this feature.

5.1 THE RAY MODEL OF LIGHT

BACKGROUND INFORMATION

The ray model is used in this chapter to discuss the properties of light as they relate to mirrors and lenses. Recall that Chapter 4 used particle and wave models of light to explain the behaviour of light. This chapter provides a good opportunity to talk about why we sometimes use different models for the same phenomenon. (Models provide a way of understanding something and for making predictions. All models have strengths and weaknesses.)

In the ray model of light, light is represented as a straight line, or ray, which shows the direction in which the light is travelling. Ray diagrams show the path of light rays, and are used to show how images in a mirror or a lens are formed.

The transmission of light rays through a material depends on the type of material.

- Light rays will pass through a transparent material unaffected.
- Light rays will pass through a translucent material but become scattered in different directions.
- Light rays will be stopped by an opaque material.

When light rays hit an opaque object, some of the light is absorbed. The light that is not absorbed is reflected or "bounced off" the surface of the object. Light rays are reflected according to the law of reflection: "The angle of incidence equals the angle of reflection." This law means that when light reflects off an object, it always strikes the object and bounces off at the same angle.

Light rays refract, or bend, when they travel between two transparent media that differ in density, for example, glass and air. The direction in which they refract is predictable:

- If a ray of light passes from a more dense medium into a less dense medium, the refracted ray will bend away from the normal. (The normal is a line perpendicular to the reflective surface.)
- If a ray of light passes from a less dense medium into a more dense medium, the refracted ray will bend toward the normal.

COMMON MISCONCEPTIONS

- An ancient misconception is that light rays come out of the eye and move to the target. In actuality, we see objects when light reflects off of them and into our eyes. When we look at something, what we see depends on our position in relation to the light we receive from the object. When we look at an object from another direction, a different pattern of light enters our eyes. Although we still see the same object, what we see is a little different because of the pattern of light our eyes receive.
- Students may believe that light rays cannot change their direction of travel since they know that light travels in straight lines. However, light does change its direction when it reflects, refracts, or transmits through a translucent material.
- Some students may believe that light is reflected away from shiny surfaces, but not reflected from other surfaces. Point out that we would not be able to see anything if light did not reflect off it.

ADVANCE PREPARATION

- For Find Out Activity 5-1A, Absorb, Reflect, Transmit, on page 173 of the student textbook, a variety of transparent, translucent, and opaque objects (see activity for specific examples) are needed for each group. You may want to gather these materials a few days before completing the activity. Note that milk is one of the materials that needs to be stored in a refrigerator. Access to an overhead projector is also needed.
- For Find Out Activity 5-1B, Observing Refraction, on page 180 of the student textbook, you will need a ray box for each group. You may need to order these ray boxes a month before completing the activity. (You will also need concave and convex lenses for Chapter 6. If necessary, order them at the same time.)
- For Find Out Activity 5-1C, When Light Reflects, on page 183 of the student textbook, you will need clear plastic cups.
- For Conduct an Investigation 5-1D, Follow That Refracted Ray!, on pages 184 and 185 of the student textbook, you will need some transparent plastic box tops, for example, from greeting cards. You may suggest that students collect these lids and bring them to class about two weeks before conducting the activity. You will also need ray boxes, vegetable oil, and rubbing alcohol.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, pp. 172–173

Using the Text

Have students read aloud the text on page 172 of the student textbook. Lead a discussion to help students recall the three types of models of light (particle model, wave model, and ray model) and why scientists proposed each of them.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-5 and 2-6, Chapter 5 Key Terms, can be used to assist students.

Using the Did You Know, p. 173

Shadows cast by laser light look interesting because the light interferes with itself to make fringes, just as water waves can. In the early 1800s, French scientist Augustin Fresnel did a mathematical analysis of the wave theory of light, and used it to predict patterns that would form when light travelled through different holes and slits. Dominique Arago tested Fresnel's predictions by shining a very small beam of light, like a laser, onto a coin. He saw a bright spot in the centre of the shadow, which can only be explained with the wave behaviour of light.

Using the Activity

Find Out Activity 5-1A

Absorb, Reflect, Transmit, p. 173

Purpose

- Students classify a variety of objects based on the objects' ability to transmit light.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2–3 days before	Gather materials. Place milk in a refrigerator. Obtain access to an overhead projector for the activity.	For each group: – variety of objects, such as a block of wood; thin and thick blocks of wax; prisms of tinted, frosted, and clear glass or Plexiglass; petri dishes of water, milk

Time Required

- 15 min

Science Background

This introductory activity allows students to test their hypotheses and observe the ability of different materials to transmit or absorb light. The objects that are opaque include the block of wood and thick block of wax. The objects that would be translucent are the thin block of wax, the frosted prism, and the petri dish of milk. The objects that are transparent include the tinted prism, the clear glass, and the petri dish of water.

Activity Notes

- Have students work in pairs or small groups. Alternatively, this activity could be done as a teacher demonstration using an overhead projector.

Supporting Diverse Student Needs

- To build vocabulary, direct students to look up the prefix “trans” (across, over, or through) used in the terms “transmit,” “transparent,” and “translucent.”
- Students with written output difficulties could sort the actual objects, instead of creating a written table in What to Do.
- Students for whom the task of creating a data table is onerous can use the prepared table on BLM 2-20, Absorb, Reflect, Transmit to record their results.
- For enrichment, challenge students to bring in objects from home that represent each type of material—transparent, translucent, and opaque. Have them test these objects to determine whether their predictions are correct.

What Did You Find Out? Answers

1. Opaque refers to the ability of an object to completely block all rays of light that strike it, by reflecting and/or absorbing the light.
2. Translucent materials allow some light to pass through them but cause the light rays to scatter in different directions, which prevents an object from being distinctively seen through them. Transparent materials allow light rays to pass through freely, allowing an object to be seen clearly through them.

Using a Demonstration

Demonstrate what conditions cause fuzzy shadows. Fuzzy shadows are shadows that do not appear sharp or have a distinctive edge. They are caused by the size of the light source shining on the object. If the light source is a single small point, the shadow’s edges are clear. However, if the light source is larger, there are more points emitting light, creating many overlapping shadows of the object, which results in fuzzy edges. Show how changing the location of the object affects the degree of fuzziness of the shadow. (The shadow is fuzzier if the object is closer to the light source and farther from the screen.)

TEACHING THE SECTION, pp. 173–182

Using Reading

Pre-reading—Key Word Concept Maps

Key word concept maps help students broaden their understanding of key word concepts. Before reading, teach the terms “reflection,” “refraction,” “ray,” “incident,” and “normal.” Draw a diagram illustrating each term on the board and leave them on display. Or, refer to the diagrams you drew before Activity 5-1B. During reading, these terms can be linked to the text. After reading, students can identify word concepts they wish to learn more about.

During Reading—GIST

Use GIST to help students distil the text material into its most important ideas or concepts. For each small section of text, have students analyze the text and summarize the key ideas using key terms in their summaries. They must reduce the passage to just 20 words that capture the gist of the text.

Supporting Diverse Student Needs

- Have students who have trouble summarizing information that they read use Think-Pair-Share to create their summaries. Each student drafts a summary, then discusses it with a classmate, and uses what they talk about to complete and refine their own summary.

After Reading—Reflect and Evaluate

Have students review their notes and choose three facts that relate to phenomena they have seen in real life. They can then write a statement about how each fact relates to real life and propose further research they may conduct for future learning.

Students can summarize what they have learned using BLM 2-21, When Light Strikes; BLM 2-

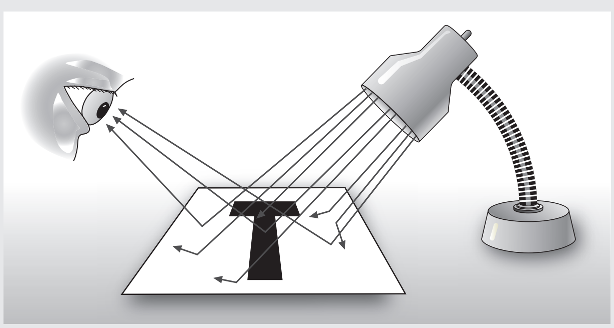
22, Reflection: Ray Diagrams; and BLM 2-23, Refraction: Light Changes Direction.

Reading Check Answers, p. 175

1. Three uses for the ray model are the following: (1) explaining how light reflects off mirrors; (2) explaining how light passes through different materials; and (3) predicting how shadows are formed.
2. An opaque material prevents any light from passing through it, while a translucent material allows most light rays to get through but scatters them in all directions.
3. A glass of water with red food colouring in it is transparent, as an object can still be clearly seen through it, though it is coloured.
4. The farther an object is from a source of light, the smaller its shadow will be.

Reading Check Answers, p. 177

1. Specular reflection occurs when an image of the surroundings is reflected from a very smooth, mirror-like surface, while diffuse reflection occurs when light is reflected off a rough surface. An image is not clearly produced but allows what is on the surface to be seen.
2. A rough surface is responsible for diffuse reflection. It reflects light randomly which does not produce a clear image.
3. The green "T" absorbs all colours of light except green, which is reflected from the print to your eyes. The rest of the page reflects white light to your eyes.



Reading Check Answers, p. 181

1. The crest of a wave is perpendicular to the direction of the wave.
2. The direction of a ray of light changes when the light travels from one medium to another medium having a different density because its speed changes.
3. The angle of refraction is the acute angle formed by the refracted ray and the normal.

Reading Check Answers, p. 182

1. If a ray of light passes from a more dense medium into a less dense medium, the refracted ray will bend away from the normal.
2. Since the light is travelling from the water (denser medium), through the air (less dense medium) to reach your eye, the coins will look like they are above their actual position (just as the fish do in Figure 5.16 on page 182).

USING THE ACTIVITIES

- Activity 5-1A on page 173 of the student textbook is best used as an introductory activity. Detailed notes about this activity can be found in Introducing the Section.
- Activity 5-1B on page 180 of the student textbook and Activity 5-1C on page 183 are best used before teaching the laws of reflection and refraction. In this way, students can investigate for themselves the behaviour of light when it reflects and refracts.
- Activity 5-1D on pages 184 and 185 of the student textbook is best used to reinforce what students have read about refraction.
- Detailed notes on doing the activities follow.

Find Out Activity 5-1B

Observing Refraction, p. 180

Purpose

- Students will observe refraction by using a ray box and a solid block of transparent material.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 month before	Order ray boxes, if necessary.	For each group: – block of glass or transparent plastic
1 day before	Gather materials. Remind students to bring rulers, pencils, and protractors.	– ray box – ruler – protractor – piece of white paper

Time Required

- 25 min

Safety Precautions

- Students should be careful not to bang or drop the ray box.
- Remind students that the area near the bulb of the ray box becomes hot after use; handle with care.

Science Background

Light rays change direction at the interface where two media of different densities meet. Light entering the glass or plastic block refracts toward the normal, since it is moving from air (a less dense material) to the glass or plastic block (a denser material). As the light leaves the block, it moves away from the normal.

The "critical angle" for a ray leaving a more dense medium and travelling into a less dense medium is the angle of incidence that produces an angle of refraction equal to 90°. When an angle of incidence is greater than this critical angle, light will not get out of the block. Instead, it will be reflected internally. The value of the critical angle depends on the combination of materials that touch each other along the boundary. For example, for light travelling from water into air, the critical angle is about 49°. Note that this total internal reflection is one of the reasons diamonds sparkle so much. (The critical angle of the diamond-to-air boundary is about 24.5°.)

Activity Notes

- Students can work in pairs.
- Students will need to know the meaning of "incident ray," "refracted ray," "normal," "angle of incidence," and "angle of refraction." Draw a diagram of each on the board, or refer to the diagrams you drew in Using the Reading. Leave these diagrams on display for students to refer to. It would be good if these terms could be taught without giving away the results of the experiment.
- It may be useful to review with students how to read angles using a protractor before carrying out the activity.

Supporting Diverse Student Needs

- Consider sketching the desired set-up to help students with reading difficulties follow the instructions.
- To ensure that students internalize the correct interpretation of the activity, you could have them think about their own answers to What Did You Find Out? questions 2 and 3, then discuss the answers with a partner before they record them. If some students have written output difficulties, pairs of students could work together to record answers after their discussion.
- For enrichment, talk with students about the critical angle (the angle at which light rays will not leave a dense medium to enter a less dense medium, but will reflect back into the more dense medium). Have students find and measure the critical angle for the light moving out of the block. For a glass-to-air boundary, the critical angle is approximately 41°.

What Did You Find Out? Answers

1. (a) The light ray passing through the glass block changes direction twice, once at the air-to-glass boundary as the light enters the block, and a second time at the glass-to-air boundary as the light exits.
   (b) The path of the light is visible at the base of the glass, where the glass meets the table.
2. (a) The light ray entering the block bends toward the normal.
   (b) The light ray leaving the block bends away from the normal.
   (c) The speed of light is slower in glass than in air.
3. If the two sides of the block are parallel, then the direction in which the light ray travels after it leaves the block is parallel to the direction of the ray before it entered the block.

Find Out Activity 5-1C

When Light Reflects, p. 183

Purpose

- Through investigation, students observe whether or not light reflects off liquid surfaces in the same way it reflects off a solid mirror.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials. Make copies of BLM 2-24, How Do Two-way Mirrors Work?	For each individual or pair: – clear plastic cup – water – paper – ruler – wooden pencil

Time Required

- 15 min

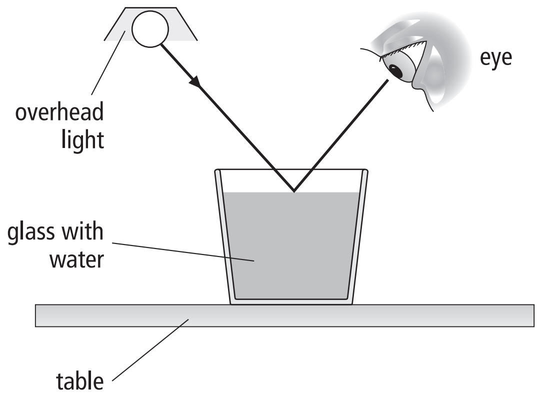
Safety Precautions

- Students should wipe up any spills immediately.

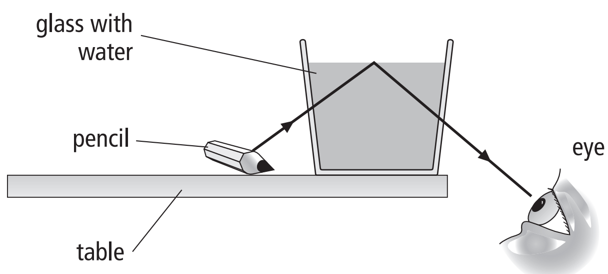
Science Background

Any interface between materials of different densities will have the ability to reflect some light off its surface, even if both materials are transparent. An example of this phenomenon is when sunlight hits the surface of a clear calm lake. When the Sun's rays strike the still surface, the light can reflect in a way that produces a mirror-like reflection of the surroundings. (Recall the picture on page 170 of the student textbook.) The law of reflection applies regardless of the materials used. That is, the angle of incidence is always equal to the angle of reflection.

Students' diagrams for step 3 in What to Do (showing the overhead lights reflecting off the water's surface) should be similar to the following diagram:



Students' diagrams for step 6 (showing the pencil reflecting off the underside of the water's surface) should look like the following:



Note that as the light ray moves from air to water and back to air, it will refract. It is not necessary for students to show this process in their diagrams.

Activity Notes

- This activity requires close-up, individual observation, and uses inexpensive, readily available materials. Students should conduct the activity individually or in pairs.
- It may be helpful to review the components of ray diagrams before students begin the activity. Remind students to place arrows on the rays to indicate the direction of light travel.
- Because of the use of water, this activity is potentially messy. Have paper towels or cloths ready for students to wipe up any spills.
- Point out to students that only some of the light in step 6 reflected off the bottom of the air-water interface. If they look from the top, they can see the pencil, indicating that some of the light passed through the interface. To illustrate how we make use of partial reflection, hand out BLM 2-24, How Do Two-way Mirrors Work?

Supporting Diverse Student Needs

- Allow students with written output difficulties who have difficulty writing about what happens to answer the What Did You Find Out? questions using only labelled diagrams.
- This activity is a good activity for visual-spatial learners.
- For enrichment, have students repeat the experiment using an oil-water interface or an oil-air interface and compare their results to the air-water interface.

What Did You Find Out? Answers

1. (a) Some of the light that struck the lower flat surface between the air and water reflected back down, though some also passed through to the top side.
   (b) Students will find some answers to this question on BLM 2-24, How Do Two-way Mirrors Work? Groups of students brainstorming together may come up with some creative ideas. Students' answers could include reflective sunglasses, two-way mirrors, and teleprompters.
2. (a) Tapping the glass caused small waves to form on the surface of the water.
   (b) The small waves made the surface of the water uneven, causing the reflection of the pencil to become distorted.
3. During reflection, the direction in which the light travels is changed after hitting the surface. If the light strikes the surface at an angle, then it bounces off at the same angle but on the other side of the normal.
4. Light reflects off both liquid and solid surfaces according to the same reflection principle; that is, the angle of incidence equals the angle of reflection.

Core Lab Conduct an Investigation 5-1D

Follow That Refracted Ray!, pp. 184–185

Purpose

- Students design an investigative procedure to find out if there is a pattern that describes the path of light during refraction.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2 weeks before	Have students collect and bring in transparent plastic box tops.	For each group: – ray box – sheet of white paper – transparent plastic watertight tray (for example, the plastic top from a box of greeting cards) – ruler – protractor – water – vegetable oil – rubbing alcohol
1 day before	Gather other materials. Remind students to bring rulers, pencils, and protractors.	

Time Required

- 40 min

Safety Precautions

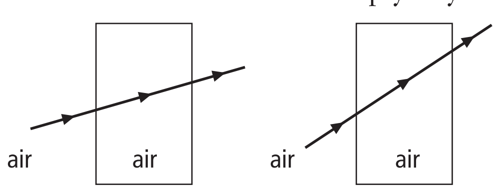
- Students should be careful not to bang or drop the ray box.
- Remind students that the area near the bulb of the ray box becomes hot after use; they should not touch it.
- Remind students not to taste anything in the science lab.
- Students should wipe up any spills immediately.

Science Background

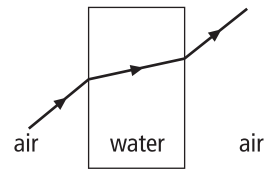
When light travels between two media with different densities, there is a pattern to the way it refracts. When light travels from a less dense material to a more dense material, the light ray bends toward the normal. When light travels from a more dense material to a less dense material, the light ray bends away from the normal.

Students' diagrams will vary, depending on the angles of incidence that they use. The following diagrams summarize the general observations in this investigation. Note that this activity assumes that the plastic tray is very thin; otherwise, there would be some refraction as the light travels through the plastic material itself since it has a density different from the medium surrounding it.

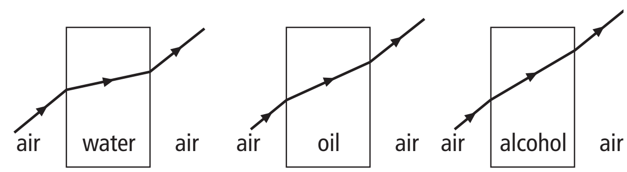
Step 4(a): When light travels from the air, through the empty tray, and back into the air through the opposite side of the tray, it travels in a straight line since the medium inside the empty tray is also air.



Step 4(b): When light travels from air to water, the light refracts (bends) toward the normal. When light travels from water to air, the light bends away from the normal. If the plastic tray has parallel sides through which the light enters and exits, the exiting ray will be parallel to the entering ray.



Step 4(c): When light travels into and out of a liquid other than water, the general pattern will be the same as it is for water but the precise angles of refraction will be slightly different due to the different densities. The densities of water, vegetable oil, and rubbing alcohol are 1 g/mL, 0.91 g/mL, and 0.79 g/mL, respectively. Since vegetable oil and rubbing alcohol are both less dense than water, the light will bend less than it does when it enters water.



Activity Notes

- Have students work in pairs or small groups. Give them time to discuss and formulate their hypothesis before they begin.
- The textbook asks students to obtain teacher approval for their procedure before conducting their experiment. You may decide to read through the entire investigation and the questions with students so they know what their procedure must accomplish before they begin. Look for procedures that allow students to complete the specified drawings and to answer the questions in the Analysis section, as well as the Conclude and Apply section.
- It may be useful to review with students the components of ray diagrams, and how to read angles using a protractor, before carrying out the activity.
- Because of the use of various liquids, this activity is potentially messy. Have paper towels or cloths ready for students to wipe up any spills.

Supporting Diverse Student Needs

- Give students who have trouble organizing their thoughts on paper, or trouble thinking visually, four pieces of paper. Have them write each of the words "air," "water," "oil," and "alcohol" at the bottom of each piece. They can use these pages to record their diagrams, as they carry out the activity. (See Procedure, step 4.) For students who have trouble measuring angles, use tracing paper. To compare refraction with different media, students can simply place one diagram over another.

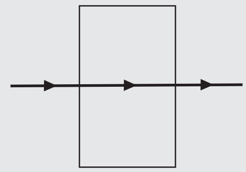
- Some students may need to be reminded of how to use a protractor—especially how to line it up with the rays they have drawn and which scale to focus on.
- Some students may have difficulty writing answers to Conclude and Apply, but may be more able to act them out, and thus provide additional reinforcement of the conclusions for the rest of the class.
- There are many roles in this activity, such as designing and setting up apparatus, recording using words or diagrams, and identifying patterns. Grouping together students who have a variety of learning styles will provide all students with opportunities for success in many areas.
- For enrichment, have students draw ray diagrams to predict the path that light will take when travelling through oil-water-oil, water-oil-water, and rubbing alcohol-oil-water combinations. Allow students to set up multiple trays of the different liquids to test their predictions. Ask them whether the pattern for the path of light during refraction held in each of these cases.

Analyze Answers

1. The normal should always be perpendicular to the edge of the new medium.
2. Students' answers will vary, depending on where they positioned the ray box.

Conclude and Apply Answers

3. In this investigation, light bends toward the normal when it travels from air into another medium such as water. Students should have observed similar results. However, students' results may or may not have supported their group's hypothesis.
4. When the angle of incidence increases, the size of the angle of refraction also increases.
5. When the angle of incidence is the same, the size of the angle of refraction will decrease if the liquid it enters is denser than water. If the liquid is less dense than water, the angle of refraction will increase.
6. A light ray moves away from the normal when it travels from a medium such as water into air.
7. Yes, there is an angle of incidence for which there is no change in the direction of the light. This situation occurs when the angle of incidence is 0°—that is, when the incident ray falls along the normal itself, so too will the refracted ray.



8. Students' answers may vary slightly, but should convey the pattern that describes the path of light during refraction: light bends toward the normal when it enters a denser medium, and light bends away from the normal when it enters a less dense medium.

USING THE FEATURE

Science Math Connect: How Big Is Earth?, p. 186

This feature is an example of how mathematical reasoning (alternate interior angles) and measurement (angles and distance) can be used to determine something that is impossible to measure directly (the circumference of the Earth).

In geometry, students have seen that alternate interior angles are equal. To remind them of this fact, draw two parallel lines and then a third line that cuts through both. The resulting "Z" shape contains inside angles that students can measure with a protractor, showing that they are indeed equal. Have them look at the diagram on page 186 of the student textbook, and try to find the "Z" in the diagram. The alternate interior angles are those labeled α and β. Eratosthenes measured α and used mathematical reasoning to conclude that β, the angle formed by the extension of the flagpoles in Alexandria and Syene, was the same as α. After hiring someone to measure the distance between the two cities by pacing it out, Eratosthenes was able to find the circumference of Earth using the calculations described in the text.

Science Math Connect Answers

1. Since Earth is a sphere, with a curved surface, two vertical flagpoles in different locations cannot be parallel. If they were, they could not both point to the centre of the Earth.
2. Since the Sun is very far away, we can assume that all of the Sun's rays that strike the Earth's surface are essentially parallel. A straight line that passes through the top of the flagpole in Alexandria and the centre of Earth crosses the parallel light rays coming in from the Sun (see diagram on page 186 of the student textbook). The angles formed by the extensions of the

flagpoles to the centre of the Earth and by the shadow of the flagpole at Alexandria are therefore alternate interior angles, which have been proven to be equal in geometry.

3. The alternate interior angle was one fiftieth the circumference of the Earth. If the distance between Syene and Alexandria had been 500 km, then the circumference of Earth would be 50 × 500 km, or 25 000 km.

SECTION 5.1 ASSESSMENT, p. 187

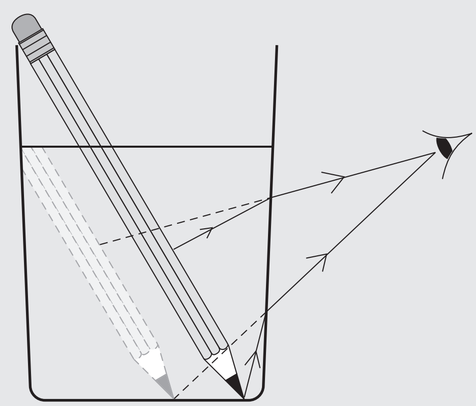
Check Your Understanding Answers

Checking Concepts

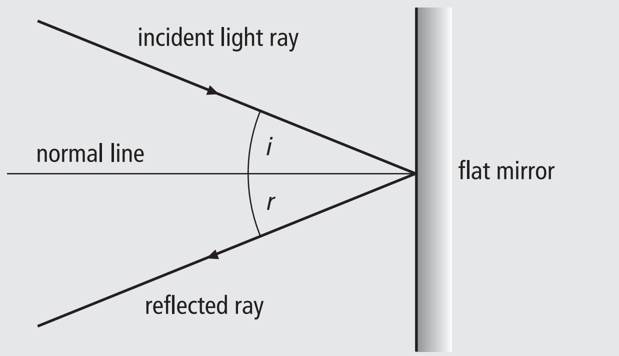
1. (a) Translucent and transparent objects both can transmit light, but an object can be seen clearly through a transparent material. Translucent materials scatter the light rays in all directions.
   (b) Transmitted and absorbed light rays both enter an object, but only transmitted light rays continue to pass through the object, while absorbed light rays are not allowed to pass through.
   (c) Reflection and refraction are both processes that affect the direction in which light travels. Reflection causes the light rays to bounce off a surface, according to the law of reflection, while refraction causes the light rays to be bent as they pass through a medium of different density.
2. If the angle of incidence is 43°, then the angle of reflection is also 43°.
3. Students' answers could include the following: Imagine the movement of light using the wave model. As the front of the light wave moves into water, it begins to slow down. However, the part of the light wave that has not yet hit the water is still moving quickly, which causes the light wave to turn, changing the direction of the light wave.
4. You can see your reflection in a smooth piece of aluminum foil because all the light rays striking the surface reflect uniformly, allowing an image to be seen in its reflection. You cannot see your reflection in a crumpled ball of foil because the light rays bounce off the uneven surface randomly, preventing the formation of a clear reflected image.
5. Specular reflection produces an image of the surroundings, while diffuse reflection allows you to see what is on the surface itself. If you see your own reflection in a shiny object, you are experiencing specular reflection.

Understanding Key Ideas

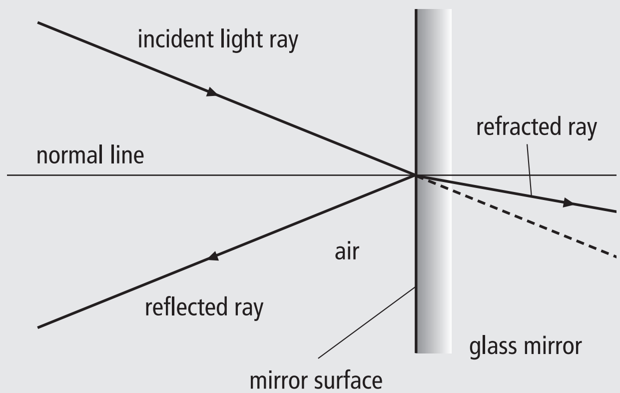
6. Shadows demonstrate rectilinear propagation because they are cast when an object blocks the light rays striking it. These light rays do not curve around the object, so a dark area forms behind the object, while the light rays on either side of the object continue in a straight line until they hit a surface.
7. (a) In a ray diagram, the normal is an imaginary line that is perpendicular to the reflecting surface. It is usually drawn where the incident ray meets the surface.
   (b) The term "normal" has the same meaning when representing refraction as when representing reflection. In a ray diagram showing refraction, this normal is extended on the other side of the surface where the incident ray strikes it.
8. Students' explanations will vary, but should mention that the light rays from the part of the pencil above the water will travel in a straight line to the eye. The light rays from the part of the pencil under the water, however, will refract when they travel from water to air. Our eye will interpret the light rays it sees as being straight, and will perceive the pencil to be in a different place than where it actually is.



9. (a) and (b)



10.



11. When the pages of a book are too smooth or glossy, the text can be difficult to read because of the high amount of specular reflection. Slightly rougher paper does not have the same glare, as the reflected light is scattered in different directions.

Pause and Reflect Answer

Students' answers could include the following reasoning: Since X rays and gamma rays are part of the electromagnetic spectrum and travel like waves, just as light does, then these invisible forms of radiation also have the property of reflection. However, like all other light waves, they can reflect only if the material they hit does not absorb or transmit them. It is not obvious which kinds of materials will reflect these particular kinds of rays. (Scientists now work with gold, carbon, and silicon, among other materials.)

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

5.2 IMAGES IN PLANE MIRRORS

BACKGROUND INFORMATION

This section discusses how plane mirrors can be used to form images, and why reflected images have the properties that they do. Image size, distance, and orientation are all consistent with the light coming from an object behind the mirror, with the exception that left is switched with right, and vice versa. The text develops these ideas by using ray diagrams to show how light coming from various parts of an object reflects off the mirror and enters the eye of the observer.

The features of an image can be summarized by the acronym SPOT: Size, Position (distance from the mirror), Orientation (upright or inverted), and Type (real or virtual). Note, that in some resources, the acronym SALT is used instead to summarize the same four characteristics: Size, Altitude (upright or inverted), Location, Type.

The characteristics of images in plane mirrors are the following:

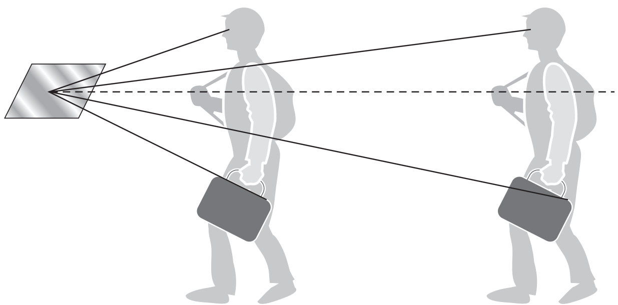
S Image size is equal to object size.
P Image distance is equal to object distance.
O The image is upright. (Its orientation is the same as that of the object.)
T The image is virtual. (The image appears behind the mirror.)

The image is reversed in a plane mirror, right to left and left to right, compared to the object being reflected. This feature is called lateral inversion.

COMMON MISCONCEPTIONS

- Some students might think that to be seen in a mirror, the object must be directly in front of the mirror, or in the line-of-sight from the observer to the mirror. Examples of plane mirrors used to "see" objects around the corner (e.g., submarine periscope, dentists' mirrors) will convince students that this belief is a misconception.
- Some students might believe that if you move far enough away from a small flat mirror, you will be able to see more of yourself in the mirror. Mount a mirror on the wall and have students try it. They will see that this belief is not true. The reason is simple geometry.

In the diagram above at the right, the lowest point the person can see in the mirror is the top of his lunchbox. He does this by looking at the very bottom of the mirror. The angle of reflection is the same as the angle of incidence. When the person backs up, the lowest point he can see (again, by looking at the very bottom of the mirror) is still the top of his lunch box.



ADVANCE PREPARATION

- For Find Out Activity 5-2A, Reflections of Reflections, on page 188 of the student textbook, small plane mirrors are needed for each group.
- For Conduct an Investigation 5-2B, Demonstrating the Law of Reflection, on pages 192 and 193 of the student textbook, you will need ray boxes, small plane mirrors with support stands, and small objects with pointed ends (e.g., pencil, nail) for each group. You may want to gather these materials a few days before completing the activity.
- For Conduct an Investigation 5-2C, Applying the Law of Reflection, on page 194 of the student textbook, you will need ray boxes, and small plane mirrors with support stands.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 188

Using the Text

Lead a discussion on different kinds of mirrors that students may have seen (store surveillance mirrors, automobile side and rearview mirrors, dressing room mirrors, make-up mirrors, fun house mirrors, dental mirrors used by dentists, telescope mirrors). Have students decide which of these mirrors are plane mirrors. How do they know?

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-5 and 2-6, Chapter 5 Key Terms, can be used to assist students.

Using the Activity

Find Out Activity 5-2A

Reflections of Reflections, p. 188

Purpose

- Students determine how many reflections they can see in two plane mirrors.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials. Remind students to bring protractors.	For each group: – 2 plane mirrors – protractor – masking tape – paper clip

Time Required

- 20 min

Safety Precautions

- Mirror edges can be sharp. Advise students to handle glass mirrors and bent paper clips carefully.

Science Background

The angles 72°, 90°, and 120° divide a circle (360°) into five, four, and three equal parts, respectively. This division turns out to be the key to the pattern of the number of images seen. For example, at 72°, the paper clip will be seen $\frac{360}{72} = 5$ times, that is, the actual paper clip plus 4 reflections of it. For 90°, there will be the actual paper clip plus 3 reflections.

This relationship can also be used to open the mirrors to a particular angle. For example, if you start at a 90° angle and expand it to the exact point where four paper clips are reduced to three paper clips, the angle will measure 120°.

Activity Notes

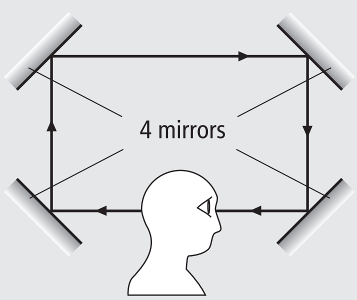
- Have students work in pairs or small groups.
- It may be useful to review with students how to read angles using a protractor before carrying out the activity.

Supporting Diverse Student Needs

- Tell students who have difficulty designing a data table to use the following three headings: "Angle between mirrors," "Number of images in right mirror," and "Number of images in left mirror."
- Students with written output difficulties may prefer to answer What Did You Find Out? question 2 by demonstrating or by drawing a diagram.
- This activity is a good hands-on activity for visual-spatial learners as well as logical-mathematical learners. Having learners of both types in each group will help ensure success in carrying out the activity and analyzing the results.
- For enrichment, have students close the mirror until they can see exactly six paper clips. See if they can predict the angle (60°), then measure and check their prediction. Have them explain their reasoning/result.

What Did You Find Out? Answers

1. Students' answers could include the following: The smaller the angle between the mirrors, the greater the number of reflections, or vice versa (the larger the angle between the mirrors, the fewer the number of reflections).
2. Two mirrors could be used to see the back of your head, but only from an angle. To be able to look straight ahead and see the back of your own head as if you were directly behind it, a minimum of four mirrors is needed.



How to view the back of your head

Using a Demonstration

This is a neat demonstration to use as a follow-up to Find Out Activity 5-2A. Set up two plane mirrors at an angle of exactly 90°. Then when you look into them, your "reflection" shows what others see you as, without the right-to-left and left-to-right image reversal that we are used to seeing in a plane mirror. For example, if you raise your right arm in front of this angled mirror, the image will raise the true right arm, not the mirror image "left" arm. Some students may be able to draw a diagram to explain how this system of mirrors works.

TEACHING THE SECTION, pp. 189–191

Using Reading

Pre-reading—Predict-Read-Verify

Break the section up into manageable chunks for students. Some suggested chunks are the following:

- Plane Mirrors
- Predicting Image Characteristics
- Using Plane Mirrors

Use the chunks as topic titles for discussion. Ask students what they think the title means and to make a prediction about what they will learn. They then read the sections and compare their predictions to what they learned.

During Reading—Note Taking

Encourage students to take notes as they read through each chunk. They can rewrite the topic titles in the form of questions to which they will find the answers as they read the section. For example, "What are plane mirrors?" "What are the characteristics of the images formed in plane mirrors?" "Where are plane mirrors used?" In addition, ask them to find information as they read to help answer the question, "Why does an image appear to be *behind* the mirror?"

Supporting Diverse Student Needs

- Provide plenty of opportunities for visual-spatial and body-kinesthetic learners to examine reflections around the classroom to help them experience how our eyes naturally extend the light rays from a reflection to form a virtual image behind the mirror and to see examples of the common characteristics of reflections in plane mirrors.

After Reading—Reflect and Evaluate

Have students review their notes and choose three facts that they predict will be true for curved mirrors, as well. They can then write a statement as to why they think they will be true and propose an experiment they could conduct to find out.

Students can apply what they have learned about plane mirrors using BLM 2-25, Mirror Images; BLM 2-26, What You See Is What You Get; and BLM 2-27, Sight Lines.

Reading Check Answers, p. 191

1. Your brain sees an image behind a plane mirror because it knows that light travels in straight lines so it traces the path of the reflected rays and extends them until they meet behind the mirror.
2. A virtual image is an image located behind the mirror. It is virtual because no rays actually go to or from the image.

3. An image in a plane mirror can be described as being the same size as the object, the same distance from the mirror, standing upright (if the object is upright), virtual, and reversed.

USING THE ACTIVITIES

- Activity 5-2A on page 188 of the student textbook provides a hands-on introduction to investigating reflections. Detailed notes about Activity 5-2A can be found in Introducing the Section.
- Activity 5-2B on pages 192 and 193 of the student textbook is best used after the initial discussion of plane mirrors on page 189.
- Activity 5-2C on page 194 of the student textbook is best used after students have read about the characteristics of images formed in a plane mirror on page 190.
- Detailed notes on doing the activities follow.

Core Lab Conduct an Investigation 5-2B

Demonstrating the Law of Reflection, pp. 192–193

Purpose

- Using ray boxes and plane mirrors, students draw ray diagrams to demonstrate the law of reflection. They form and test a hypothesis about the relationship between the angle of incidence and the angle of reflection.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Gather small objects (shorter than the mirror) with a pointed end, such as a pencil or nail.	For each group: – ray box – small plane mirror (about 5 cm by 15 cm) with support stand – small object with a pointed end – protractor – ruler – pencil – sheet of blank paper
1 day before	Gather other materials. Remind students to bring protractors and rulers. Make copies of BLM 2-28, Plane Mirror Template (optional).	

Time Required

- 30 min

Safety Precautions

- Caution students that the edges of the mirrors may be sharp, and that mirrors are fragile and can break easily.
- Students should be careful not to bang or drop the ray box.
- Remind students that the area near the bulb of the ray box becomes hot after use; they should not touch it.

Science Background

A scientific law is an observation that has been observed so many times by so many scientists that scientists have concluded that it will always happen. There are two laws of reflection:

1. The angle of incidence is equal to the angle of reflection.
2. The incident ray, the reflected ray, and the normal all lie in the same plane.

Activity Notes

- To reduce the number of ray boxes needed, students can work in small groups of three or four.
- It may be useful to review with students the terms“incident ray,” “reflected ray,” and “normal” before carrying out the activity. Also, review how to read angles using a protractor.
- Students already know that light travels in straight lines. They may have read that the angle of reflection equals the angle of incidence. Have them apply this information to predict what they think will happen to a real ray of light when it is reflected off a real mirror.
- To direct the beam of light, use the ray box attachment that has one slit in it.

Supporting Diverse Student Needs

- Partner students who have reading difficulties with students who have stronger reading skills to help them interpret the procedure instructions. Visual-spatial skills will also be helpful for students to interpret the instructions.
- If pairs or groups have trouble following the instructions, you might demonstrate Procedure steps 1 to 3, then have pairs compare their results after steps 7 and 9 to be sure they are on the right track.
- Conclude and Apply question 2 assumes students are familiar with the mathematical word “plane.” If some are not, tell them a flat surface is called a plane.
- Students can use BLM 2-28, Plane Mirror Template, to draw their ray diagrams on.

Analyze Answers

1. There would be an unlimited or infinite number of possible rays that could be drawn from point P to the mirror.
2. The angle of reflection equals the angle of incidence.

3. The distance between the object and the mirror is equal to the distance between the image and the mirror.

Conclude and Apply Answers

1. The angle of incidence is equal to the angle of reflection. This pattern may or may not agree with students' hypothesis, depending on what they wrote.
2. A flat surface is called a plane. The incident ray, reflected ray, and the normal all lie in the same plane.
3. The distance from the image to the mirror is equal to the distance from the object to the mirror.

Core Lab Conduct an Investigation 5-2C

Applying the Law of Reflection, p. 194

Purpose

- Students use a ray diagram and the law of reflection to make predictions about an image, and then use a ray box to test their predictions.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials. Remind students to bring protractors and rulers.	For each group: – ray box – small plane mirror with support stand – protractor – ruler – pencil – sheet of blank paper

Time Required

- 40 min

Safety Precautions

- Caution students that the edges of the mirrors may be sharp, and that mirrors are fragile and can break easily.
- Students should be careful not to bang or drop the ray box.
- Remind students that the area near the bulb of the ray box becomes hot after use; students should not touch it.

Science Background

A ray diagram and the law of reflection can be used to predict the position of an image. The steps are as follows:

1. Label the endpoints of the object A and B.
2. Draw two incident rays from point A at different angles to the mirror.
3. For each incident ray, use the law of reflection (and a protractor) to draw the corresponding reflected ray.
4. Extend both reflected rays behind the mirror until they meet. This is the image of point A.
5. Repeat steps 2 to 4 at point B to find the image of point B.
6. Use the images of points A and B to draw the image of the object behind the mirror.

Activity Notes

- To reduce the number of ray boxes needed, students can work in small groups of 3 or 4.
- In step 3 of the procedure, students are asked to make a ray diagram and draw an image by extending the reflected rays behind the mirror. It may be useful to review with students how they did this step in Activity 5-2B on pages 192 and 193.
- When using a ray diagram to draw an image of the pencil (with ends labelled "A" and "B"), students should realize that they need to draw a set of two incident rays for each endpoint.
- To direct the beam of light, use the ray box attachment that has one slit in it.

Supporting Diverse Student Needs

- Partner students who have reading difficulties with students who have stronger reading skills to help them interpret the procedure instructions.
- This activity, like many others in this unit, is a good hands-on activity for visual-spatial learners. Placing these students in groups with other types of learners can help everyone improve their visual-spatial skills.
- Conclude and Apply questions could be answered in a "write-around," with each student in a group having a chance to contribute ideas. Students can then select ideas from their group's answer to share with the class.

Analyze Answers

1. Students' answers will vary, depending on how accurately they drew the incident and reflected rays, and measured the angles of incidence and reflection.
2. Students' answers will vary, depending on the accuracy of the image that they drew.

Conclude and Apply Answers

3. Students' answers could include the following: The angle of incidence and/or angle of reflection was measured incorrectly. The reflecting surface (usually the back) of the plane mirror was not placed exactly on the line drawn.

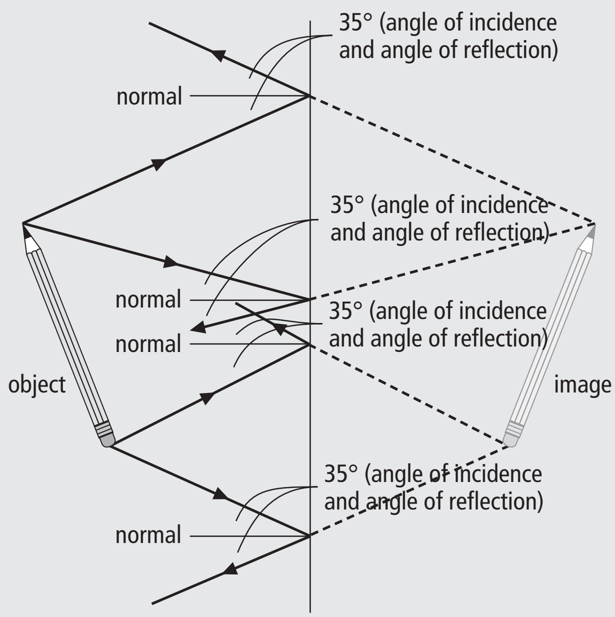
4. Students' answers could include the following: Measure angles carefully. It could be helpful to use a sharp pencil to draw the rays of light. Place the plane mirror exactly on the line.

SECTION 5.2 ASSESSMENT, p. 195

Check Your Understanding Answers

Checking Concepts

1. (a) The light rays appear to be coming from behind the mirror.
   (b) The light rays are actually reflecting off the object, then the surface of the mirror.
2. Student's diagrams will depend on the object chosen. Sample answer:

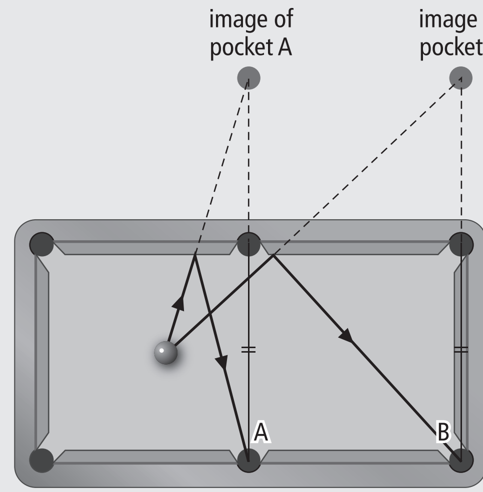


object length = 32 mm
image length = 32 mm

3. The image produced by a plane mirror is reversed, right to left and left to right, compared to the object it reflects.
4. Image size is equal to object size. Image distance is equal to object distance. Image is upright. (It has the same orientation as that of the object.)
5. Students' answers could include the following: bathroom mirror, rearview mirror in a car, dental mirror, vehicle inspection mirror, periscope.

Understanding Key Ideas

6. In order to shoot the ball into the desired pocket, you can aim at the "image" of that pocket, using the side of the table as a mirror. In this way, the ball will bounce off the side of the table at the same angle at which it strikes the side of the table, allowing it to head straight into the target pocket.



7. That person should be able to see your face. The light that travels from that person and reflects off the mirror to your eyes would be the same path as the light that travels from you to the mirror to that other person.

Pause and Reflect Answer

Since the image formed in a plane mirror is reversed compared to the object being reflected, the letters at the front of an ambulance are purposely written backward so that their reflection in a car's rearview (plane) mirror would be reversed and the driver would be able to read the word correctly.

Other Assessment Opportunities

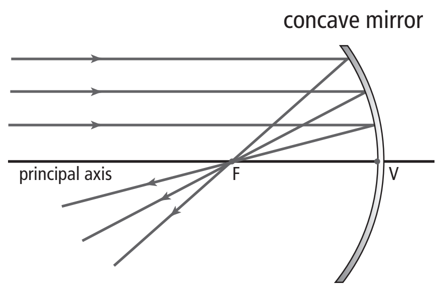
- Consult the Unit front matter for a list of applicable Assessment BLMs.

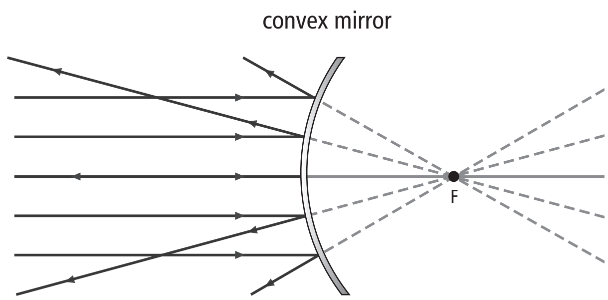
5.3 IMAGES IN CURVED MIRRORS

BACKGROUND INFORMATION

A curved mirror is a mirror with a curved reflective surface. A concave mirror (or converging mirror) is one in which the surface curves inward, while a convex mirror (or diverging mirror) is one in which the surface bulges outward.

All curved mirrors have a principal axis, vertex, and focal point (or focus). The principal axis is the line normal (perpendicular) to the centre of the mirror. The point at which the principal axis meets the mirror is called the vertex. When a set of light rays parallel to the principal axis hits the curved mirror, their reflected rays will meet at the mirror's focal point. For a concave mirror, the reflected rays converge at one point in front of the mirror. For a convex mirror, the reflected rays diverge from the mirror's surface and never meet. However, if these reflected rays are extended backward behind the mirror, they will meet at one point.





As with plane mirrors, ray diagrams can be used to determine the characteristics of the image formed in these two types of curved mirrors. If you draw the ray diagrams for objects in different positions, you will see that the characteristics for an image in a concave mirror depend on the distance between the mirror and the object being reflected. On the other hand, the characteristics for an image in a convex mirror remain the same regardless of the object's distance from the mirror. Images in a concave mirror can be larger or smaller than the object, upright or inverted, and real or virtual. Images in a convex mirror are always smaller than the object, upright, and virtual.

Images in a curved mirror can be predicted by drawing three incident rays and determining where the reflected rays (or their extensions) intersect. Note that it really only requires two of the rays to find the location of the image but the third ray serves to confirm that the other two rays were drawn correctly if all three intersect in the same place.

COMMON MISCONCEPTIONS

- Students may believe that the focal point of a concave mirror is where the image forms. This belief is not the case. Parallel rays coming toward the mirror are all made to converge at the focal point, but this result does not mean the image forms there. Students will determine how to find images in a concave mirror using ray diagrams on page 198 of the student textbook.
- Students may believe that convex mirrors always make objects appear smaller and concave mirrors always make objects appear larger. Moving the spoon in Activity 5-3A farther and closer should help them see that this belief is not always the case. The size (and other characteristics) of the image in a concave mirror depends on the distance the object is from the mirror.
- Students may have difficulty distinguishing between real and virtual images, given that both are seen by the observer. Point out that while you can see both real and virtual images, a real image can be captured on a screen, if you hold the screen where the light rays converge. A virtual image cannot be captured on a screen, because the light rays do not actually converge, they just appear to.

ADVANCE PREPARATION

- For Find Out Activity 5-3A, Reflection from a Spoon, on page 197 of the student textbook, spoons with two shiny, reflective surfaces are needed. You may want to purchase a class set of these spoons a week before completing the activity, or ask students to each bring a spoon from home on the day of the activity.
- For Conduct an Investigation 5-3B, Real and Virtual Images, on page 207 of the student textbook, three concave mirrors with different curvatures, one flat mirror, and one convex mirror are needed for each group. You may want to order a class set of these mirrors one month before completing the activity. Access to a room with a window is also needed.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, pp. 196–197

Using the Text

Have students read aloud the text on page 196. Lead a discussion on other characteristics that students may have noticed that are different for images formed in curved mirrors compared to those in plane mirrors (distorted image; image size is sometimes larger, sometimes smaller than the object; image is sometimes inverted). Brainstorm uses for these types of mirrors. While the side mirrors on cars are curved, the curve is so slight that you cannot detect it by running your hand across it.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-5 and 2-6, Chapter 5 Key Terms, can be used to assist students.

Using the Activity

Find Out Activity 5-3A

Reflection from a Spoon, p. 197

Purpose

- Students investigate some general properties of curved mirrors by using a kitchen spoon.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Purchase a set of kitchen spoons or ask students to each bring one from home.	For each individual or group: – kitchen spoon

Time Required

- 10 min

Science Background

A spoon provides an excellent example of a concave and convex mirror surface. The inside of the spoon acts as a concave mirror, while the other side acts as a convex mirror. When looking at the inside of the spoon, with your face as close as possible to still see an image of your eye only, the image appears larger and upright. Here, the eye is in front of the spoon's focal point. When the spoon is moved farther away, so that your face is farther from the spoon than the focal point is, but not twice that distance, your image appears larger and inverted. When your face is more than twice the distance from the spoon than the focal point is, your image appears smaller and inverted. When looking at the bottom of the spoon, the image appears a little distorted around the edges, smaller than the image reflected on the inside of the spoon held at the same distance, and upright.

Activity Notes

- Students should carry out the investigation independently. Then they can compare results with others afterward.
- Have students wipe their spoons with a cloth at the beginning of the activity. The shinier the spoon, the clearer the image will be.

Supporting Diverse Student Needs

- Consider pairing students who have written output difficulties with students who have stronger writing skills to write the descriptions in What to Do point 5.
- Encourage students who have trouble organizing their thoughts to use a T-chart to answer What Did You Find Out? questions 1 and 2. Students could also act out answers to these questions for the class.

What Did You Find Out? Answers

1. In a plane mirror, the image size and orientation is the same as the object being reflected. However, the image on the inside of the spoon is smaller and inverted, unless you are very close to the spoon. Then the image is larger and upright.
2. The image in the bottom of the spoon is smaller than the object being reflected, but upright, as in a plane mirror.

Using a Demonstration

There is a commercial product made of two finely crafted concave mirrors that are placed facing each other. The hollow space in the middle is surrounded on all sides by reflecting surfaces except for one hole at the top. When a small object is placed inside the hollow formed by the mirrors, a three dimensional (3-D) image of the object is formed above the mirrors. The image looks completely real, but when students reach out to touch it, the object is not there. The device is available in science catalogues. (Boreal Northwest sells the device by the name "Mirage.")

Ask students why the image appears 3-D. The light coming off the object is reflected back to a single place by the special arrangement of the mirrors. When the light rays begin to spread apart from the new location, the object seems to be in this place. This demonstration can be used as an opportunity to introduce key words such as “converging rays,” “diverging rays,” “focal point,” and “real and virtual images.”

TEACHING THE SECTION, pp. 197–206

Using Reading

Pre-reading—Predict-Read-Verify

Break the section up into manageable chunks for students. Some suggested chunks are the following:

- Concave Mirrors
- Ray Diagrams for Concave Mirrors
- Using Concave Mirrors
- Convex Mirrors
- Ray Diagrams for Convex Mirrors
- Using Convex Mirrors

Use the chunks as topic titles for discussion. Ask students what they think the title means and to make a prediction about what they will learn. Have them be as specific as possible about what characteristics they think they will see in convex and concave mirrors. They can then read the sections and compare their predictions to what they learned.

During Reading—Think, Pair, Share

Ask students to read each section independently, record their thoughts, and then pair up with another student to discuss their thoughts on the text. Students should focus on how an image is formed in a concave mirror and a convex mirror, and draw the ray diagrams for each to show the similarities and differences in the image formed. Pairs should check each others’ ray diagrams and be sure they agree that they are correct.

Supporting Diverse Student Needs

- Students can draw their ray diagrams on BLM 2-29, Concave Mirror Template, and BLM 2-30, Convex Mirror Template.

After Reading—Semantic Mapping

Semantic mapping helps students demonstrate relationships between new and known information. In this section, have students use a Venn diagram to compare and contrast the concave and convex mirrors in terms of shape, properties of the images that are formed, and uses. They can also add information from the last section to compare and contrast characteristics of images seen in plane mirrors versus those seen in curved mirrors.

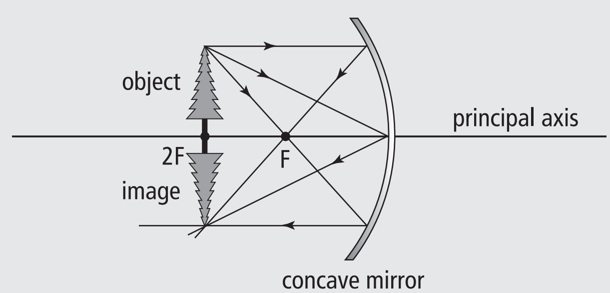
Students can apply what they have learned about curved mirrors using BLM 2-31, Different Mirror Surfaces, and extend it using BLM 2-32, Egyptian Mirror; BLM 2-33, Curved Mirrors: Images from a Distant Object; and BLM 2-34, Blind Spots in an Automobile.

Reading Check Answers, p. 202

1. If an object is between the focal point and the mirror, you need to extend the rays behind the mirror to find the image point. If the object is not between the focal point and the mirror, the image point is found where the reflected rays meet.
2. A virtual image is an image created by extending the reflected rays behind the mirror. A real image is formed when reflected rays (not extended rays) meet in front of the mirror.
3.

IMAGE FEATURES	OBJECT IS LOCATED BETWEEN F AND V.	OBJECT IS LOCATED BETWEEN F AND 2F.	OBJECT IS LOCATED BEYOND 2F.
Size	Image is larger than object.	Image is larger than object.	Image is smaller than object.
Position	Image distance is larger than object distance.	Image distance is larger than object distance.	Image distance is smaller than object distance.
Orientation	Upright	Inverted	Inverted
Type	Virtual	Real	Real

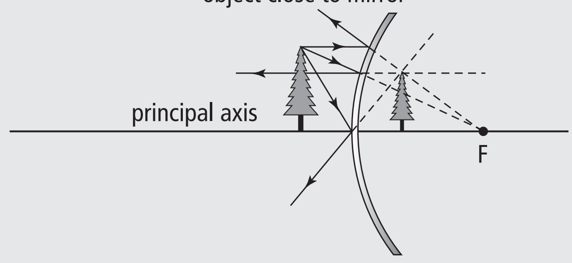
4. When the object is at a distance of twice the focal length from the mirror, the image is the same size as the object and inverted. The image is located the same distance from the mirror, directly beneath the object on the other side of the principal axis.

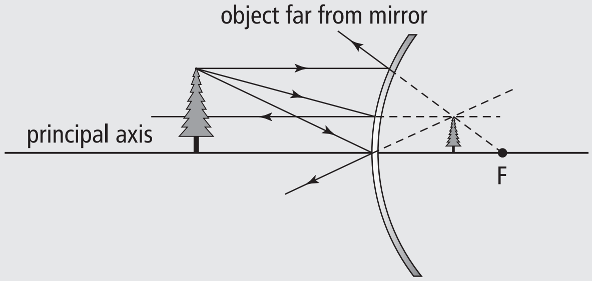


Reading Check Answers, p. 206

1. The focal point of a convex mirror is found behind the mirror, while the focal point of a concave mirror is found in front.
2. Although the rays of light that reflect from a convex mirror never meet, their extended rays do meet behind the mirror. You can use these extended rays to find the image.

3. The characteristics of an image in a convex mirror do not depend on the distance of the object from the mirror. The image is smaller, upright, closer to the mirror than the object is, and virtual in all cases.





USING THE ACTIVITIES

- Activity 5-3A on page 197 of the student textbook is best used as an introductory activity. Detailed information about this activity can be found in Introducing the Section.
- Activity 5-3B on page 207 of the student textbook is best used after students have become familiar with the characteristics of images formed in plane, concave, and convex mirrors.
- Detailed notes on doing Activity 5-3B follow.

Conduct an Investigation 5-3B

Real and Virtual Images, p. 207

Purpose

- Students will investigate several mirrors to demonstrate which can create images on a screen.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 month before	Purchase concave mirrors of different curvature, flat mirrors, and convex mirrors.	For each group: – 3 concave mirrors with different curvatures – 1 flat mirror – 1 convex mirror – white cardboard for screen
1 day before	Gather materials. Arrange to conduct the activity in a room with a window. Make copies of BLM 2-35, Real and Virtual Images (optional).	– room with a window

Time Required

- 30 min

Safety Precautions

- Caution students that the edges of the mirrors may be sharp, and that mirrors are fragile and can break easily.

Science Background

For concave mirrors of different curvatures, the rays will converge at different focal points. The greater the curvature of the mirror, the shorter the focal length. The lower the curvature of the mirror, the longer the focal length. The curvature will affect how large the image will appear on the screen. The greater the curvature, the smaller the image, and vice versa.

Activity Note

- Have students work in groups of five, where each student is assigned a particular mirror to use.
- Students can record their drawings in Conclude and Apply question 5 on BLM 2-35, Real and Virtual Images.

Supporting Diverse Student Needs

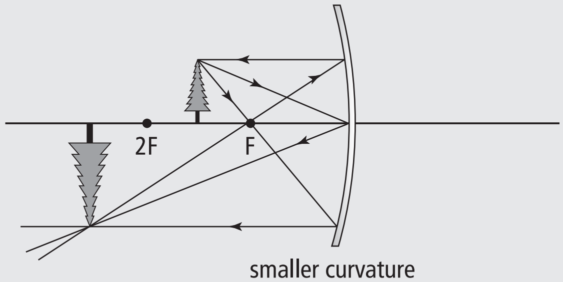
- Have students who have trouble understanding written instructions work in groups with other students who do not. One student can demonstrate the procedure with one mirror, then the other can follow with another mirror.
- In Procedure step 4, students may choose to record their observations in writing or on a diagram.

Analyze Answers

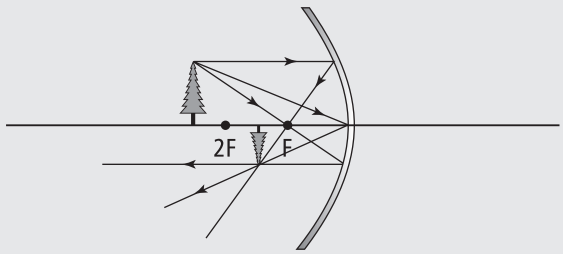
1. The concave mirrors can project an image onto the screen.
2. The size of the images on the screen is different for the different curvatures of the concave mirrors.

Conclude and Apply Answers

3. The concave mirrors formed real images, while the flat mirror and convex mirror formed virtual images. When the flat mirror and convex mirror were used, an image could not be captured on the screen.
4. The concave mirror that produced the largest image was the one with the smallest curvature.
5.



smaller curvature



greater curvature

USING THE FEATURES

Explore More, p. 198

You could challenge groups of students to design an experiment using a ray box to find the focal points of different concave mirrors. You may wish to wait until students have read about convex mirrors and have them use ray boxes to find the focal points of both kinds on the same day. (See Explore More on page 204.) The activity can then serve as a review of both convex and concave mirrors.

Science Watch: Curved Surfaces Collect Solar Energy, p. 208

After reading the feature, students could be asked to do the following:

- Answer the questions.
- Research to find out more about how these curved reflective surfaces were first made, and what some of their current applications are.
- Research to find out how differently designed solar homes work.

Science Watch Answers

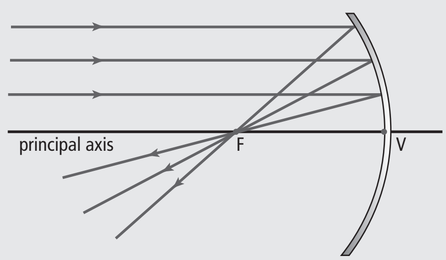
1. Curved reflective surfaces are better than flat surfaces for collecting radiant solar energy because their shape helps focus the light onto one small area where the heat can be harnessed.
2. Shiny metal surfaces are used for the curved troughs instead of glass mirrors because they are less breakable and are resistant to scratches.

SECTION 5.3 ASSESSMENT, p. 209

Check Your Understanding Answers

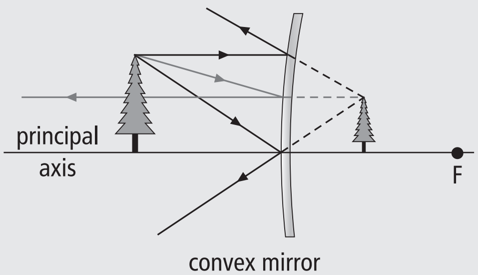
Checking Concepts

1. The three rays that allow you to predict an image in a curved mirror are the following:
   (1) The ray that travels from the top of the object parallel to the principal axis.
   (2) The ray that travels through the focal point and the top of the object before hitting the mirror (or whose extension travels through the focal point).
   (3) The ray that travels from the top of the object to the vertex.
2. To find the focal point of a concave mirror, draw rays parallel to the principal axis. Then draw their reflections. The reflections will converge at the focal point.
3.



4. Step 1: Draw a ray from the top of the tree parallel to the principal axis. Draw a reflected ray. For the concave mirror, the reflected ray will pass through the focal point. For the convex mirror, the extension of the reflected ray will pass through the focal point.
   Step 2: For the convex mirror, draw a ray from the top of the tree through the focal point. For the concave mirror, the ray will need to be extended to go through the focal point. Draw a reflected ray parallel to the principal axis.
   Step 3: For both mirrors, draw a ray from the top of the tree to the vertex, and reflecting at the same angle.
   Step 4: For both mirrors, extend reflected rays behind the mirror to find the object point.
5. Students' answers could include the following: spotlights, flashlights, overhead projectors, car headlights, lighthouses, telescopes, and satellite dishes.

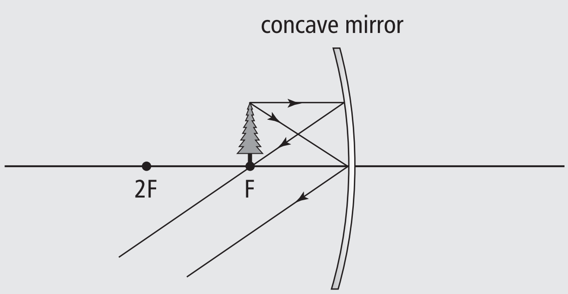
6. The reflecting surface of a convex mirror bulges outward, while the reflecting surface of a concave mirror curves inward.
7. A convex mirror always forms a virtual image since reflected rays diverge in front of the mirror, and only their extended rays meet behind the mirror.



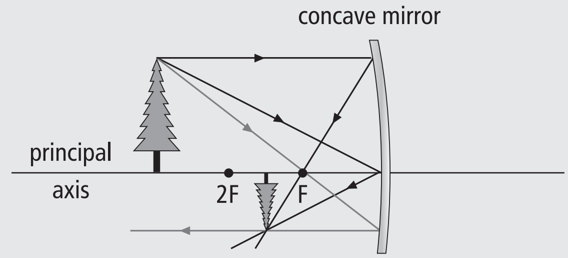
8. Students' answers could include the following: Convex mirrors allow observers to see a larger area from a single location, such as security mirrors and side mirrors on automobiles, trucks, and buses.

Understanding Key Ideas

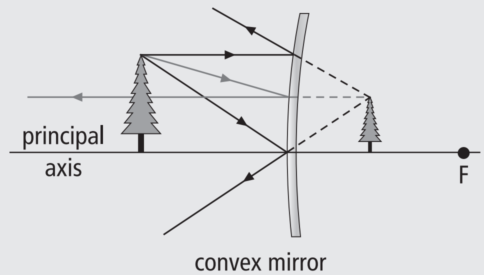
9. An object placed exactly at the focal point of a concave mirror would not produce an image because the incident ray that passes through the top of the object and the focal point is perpendicular to the principal axis, and does not go to the mirror. The other two reflected rays are parallel to each other.



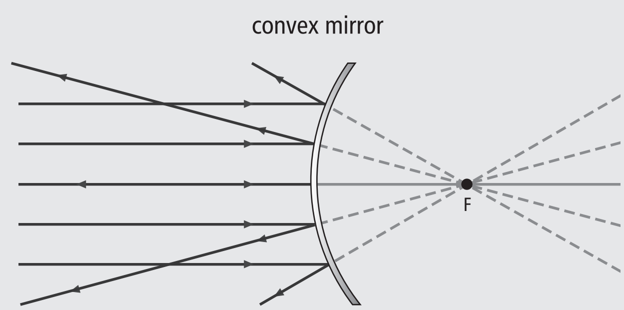
10. Concave Mirror
Depending on where students draw the object, placement and characteristics of the image will vary. For example, the image of an object more than 2 focal lengths from the mirror is smaller than the object, closer to the mirror, inverted, and real.



Convex Mirror
The image is smaller than the object, closer to the mirror, upright, and virtual.



11. By placing the bottom of the object on the principal axis, the image of the bottom of the object is also on the principal axis. This means that you do not have to draw three rays to locate it.
12. To find the focal point of a convex mirror, draw a set of parallel rays to the mirror's surface. The reflected rays will diverge (never meet), but their extended rays will meet at the mirror's focal point.



Pause and Reflect Answer

The passenger-side rear view mirror is a convex mirror. The images in a convex mirror are always smaller than the objects being reflected, which helps to widen the view of traffic behind/beside you.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

CHAPTER 5 ASSESSMENT, pp. 210–211

PREPARE YOUR OWN SUMMARY

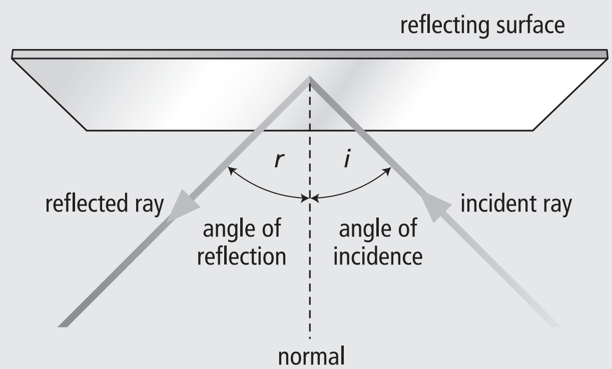
Students' summaries should incorporate the following main ideas:

1. Law of Reflection
   - When an incident ray hits a reflecting surface, the reflected ray bounces off the surface in a predictable manner.
   - The law of reflection states that "the angle of reflection equals the angle of incidence."
   - The law of reflection holds true for plane and curved mirrors.
2. Specular and Diffuse Reflection
   - A specular reflection is a reflection from a mirror-like surface which produces an image of the surroundings.
   - A diffuse reflection is a reflection from a rough surface, which does not produce a clear image but instead allows you to see what is on the surface.
   - Diffuse reflection allows us to read the print on the page because the reflected light from the white parts of the page go out in all directions; otherwise, we would see our image behind the print on the page, making it difficult to read it.
3. Refraction of Light
   - When light travels from a less dense medium to a more dense medium, it bends toward the normal.
   - When light travels from a more dense medium to a less dense medium, it bends away from the normal.
   - Refraction can cause optical illusions, such as a pencil in a glass of water that can appear to be broken or bent.
4. Plane, Concave, and Convex Mirrors
   - A plane mirror is a flat mirror. The image formed in a plane mirror appears to be the same size as the object, the same distance from the mirror as the object is, upright, and virtual.
   - A concave mirror is a mirror that curves inward. The characteristics of the image formed in a concave mirror depend on the distance the object is from the mirror.
   - A convex mirror is a mirror that bulges outward. The characteristics of the image formed in a convex mirror are the same regardless of the distance the object is from the mirror (image is smaller than object, image distance is smaller than object distance, image is upright, image is virtual).
   - A real image is an image that forms in front of the mirror, where the reflected rays meet. This image can be captured on a screen placed in the correct position.
   - A virtual image is an image that forms behind the mirror. The reflected rays do not actually meet; only the extended rays meet.
5. Ray Diagrams
   - In the ray model of light, light is represented by a straight line with an arrow on it (ray).
   - Ray diagrams indicate the path that light takes when it reflects off a surface, or refracts when travelling between two media of different densities.
   - Ray diagrams are used to show how images in a mirror or a lens are formed.
6. Uses of Mirrors
   - Some examples of plane mirrors include the following: bathroom mirror, rearview mirror, dental mirror, vehicle inspection mirror, and periscope.
   - Some examples of concave mirrors include the following: spotlights, flashlights, overhead projectors, car headlights, lighthouses, telescopes, and satellite dishes.
   - Some examples of convex mirrors include the following: security mirrors; sideview mirrors on cars, trucks, and buses; streetlights; and a disco ball.

CHAPTER REVIEW ANSWERS

Checking Concepts

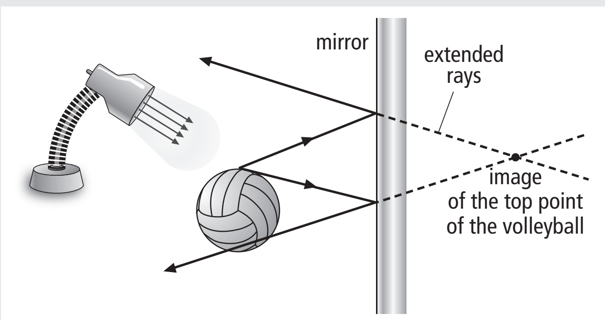
1. (a)



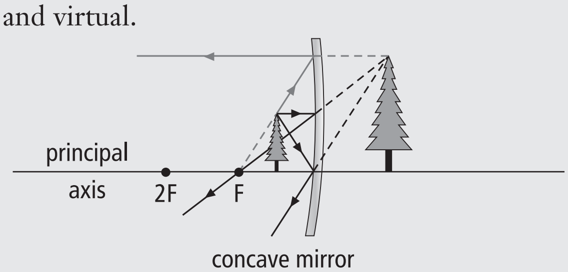
   (b) The angle between the incident ray and the normal is equal to the angle between the reflected ray and the normal. This result leads to the law of reflection: the angle of reflection equals the angle of incidence.
2. A specular reflection is a reflection from a mirror-like surface which produces an image of the surroundings. A diffuse reflection is a

reflection from a rough surface, which does not produce a clear image but instead allows you to see what is on the surface. An image of yourself in a mirror is produced by specular reflection.

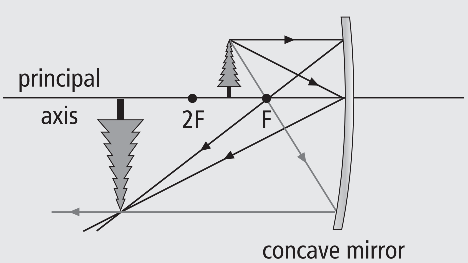
3. The reflected light from all of the white parts of the page goes out in all directions and reaches our eyes, while the black print absorbs all the light that hits it. The white paper produces diffuse reflection and allows you to see the surface of the paper, rather than a reflection of yourself on the page.
4.



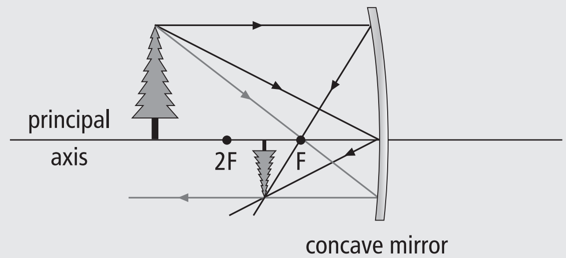
5. The image in of the volleyball is virtual since it is located behind the mirror, where the extended rays meet.
6. When the object is located between the focal point and concave mirror, the image is upright and virtual.



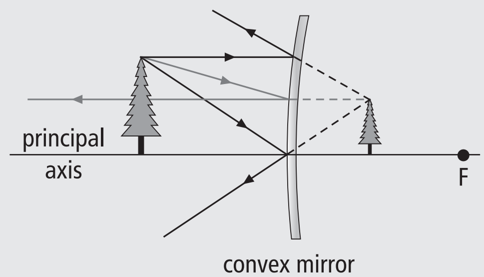
When the object is located between the focal point and two times the focal point of a concave mirror, the image is inverted and real.



7. Concave mirrors are often used for makeup mirrors or shaving mirrors because the image is larger than the object if the object is located between the focal point and the mirror.
8. At arm's length, the image of your face in a shaving mirror is smaller and inverted. As the mirror is brought closer to your face, the image becomes larger and upright.
9. In order for the image to be real, inverted, and smaller than the object, the object must be located beyond two times the focal point.



10. Since the outer surface of a piece of shiny sphere is curved outwards, it can be used to make a convex mirror.
11. The image in a convex mirror is virtual, upright, and smaller than the object.



Understanding Key Ideas

12. In specular reflection, the normals are perpendicular to the smooth surface, so all the reflected rays bounce off the surface at the same angle. In diffuse reflection, the normals point in different directions where they touch the rough surface, so the angles of reflection are different for each incoming incident ray. Nonetheless, each individual ray still obeys the law of reflection.
13. If an image appears on a screen placed in front of the mirror, the image is real. If no image appears on the screen at any point in front of the mirror, the image is virtual.
14. Placing the bottom of an object on the principal axis makes it easier to locate an image in a ray diagram because in doing so, the image of the bottom of the object will also be along the principal axis. You will not need to draw three rays to locate it.

15. The flashlight bulb is placed at the focal point of the curved reflector in a flashlight because the light emitted by the bulb at the focal point is reflected as parallel rays that provide a bright beam of light directed in front of the flashlight.

Pause and Reflect Answer

When two mirrors are used at angles with each other, we can say "the image of the girl in one mirror becomes the object for the second mirror." This result is because when the girl (original object) stands in front of one mirror, the light hitting the back of her head bounces to the mirror and produces an image of her. The second mirror treats this image as the object to be reflected.

CHAPTER 6 OPENER, pp. 212–213

USING THE PHOTO AND TEXT

The photograph of the boy trying to make a fire with a magnifying glass is sure to invoke some response from students. Many of them will probably be able to explain that the method works because the magnifying glass concentrates the Sun's rays into one spot, hot enough to ignite the dry tinder. But do they know what to do with a piece of ice, as proposed in the paragraph below the photograph? What similarities do they see between the magnifying glass and a piece of ice?

Ask students what shape the lens (ice) would have to be in order for it to be able to focus the Sun's rays. Use their responses as a lead-in to the different shapes that lenses come in. Ask, "What purpose do these different-shaped lenses serve?" In this chapter, students will learn about concave and convex lenses and how they work. They will also explore the role of lenses in human vision and optical technologies (such as microscopes, telescopes, binoculars, and cameras).

USING THE WHAT YOU WILL LEARN / WHY IT IS IMPORTANT / SKILLS YOU WILL USE

Read the What You Will Learn section aloud with students and ask them to list things they know that will help them answer the following questions:

- What is the difference between a concave lens and a convex lens?
- How does the refraction of light affect the images that are produced?
- How do optical devices magnify objects?
- How does human vision work? What are some of the ways to correct or enhance human vision?

The lists can help you determine students' prior knowledge of lenses and other optical apparatus.

Use the Why It is Important and Skills You Will Use features to discuss where lenses are used in our everyday lives. Make a list of the different products that contain a lens in it (e.g., corrective lenses, camera). Besides describing and observing, students will have an opportunity to predict, investigate, draw ray diagrams, and build a projector and pinhole camera.

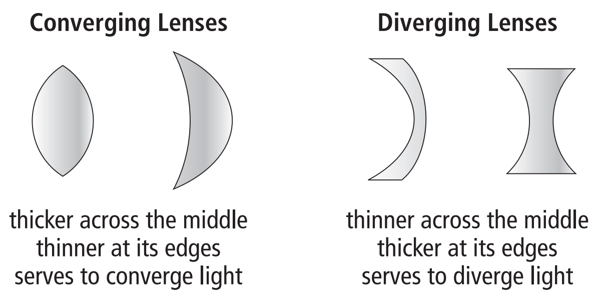
USING THE FOLDABLES™ FEATURE

Encourage students to complete this exercise as they read the chapter. The eight-page Foldable will help students summarize various aspects of convex and concave lenses, ray diagrams, human vision, and modern optical technologies. Students can use this Foldable to define new terms and to summarize key ideas for each topic. If students use graph paper to make the Foldable, they can draw accurate ray diagrams for the different types of lenses. See the Foldables section of this resource for additional information about this feature.

6.1 CONCAVE AND CONVEX LENSES

BACKGROUND INFORMATION

A lens is a piece of glass or plastic that is shaped so that parallel incident rays are made to either converge to a point or appear to be diverging from a point. Lenses come in two basic types: concave and convex. Convex lenses are those that are thicker in the middle and thinner at the upper and lower ends. Concave lenses are those that are thinner in the middle and thicker at the upper and lower ends.



There are similarities between lenses and mirrors (as described in the previous chapter). A concave lens is similar to a convex mirror because both cause parallel incident rays to diverge. This result means that in both cases the image that is viewed appears smaller than the object, but there is never any inversion of the image. A convex lens is similar to a concave mirror because both cause parallel incident rays to converge. This result means the type of image formed changes depending on the location of the object compared to the focal point. Students will investigate and compare the effects of both types of lenses in Activity 6-1A.

The details of image formation for concave and convex lenses are given in the student textbook. The importance here is to emphasize the beauty and ingenuity behind the idea that simple ray diagrams can be used to analyze very complicated optics. The application of basic principles of light, reflection, and refraction should be the main focus in this chapter.

COMMON MISCONCEPTIONS

- From the ray diagrams, or preconceived ideas, students may believe that refraction happens somewhere in the middle of the lens, instead of at the surface. The refraction actually occurs twice—as the light enters the lens, and then again as it leaves

the lens. Explain to students that the ray diagram is a simplification, but then point out that Figure 6.3 and Figure 6.4 on page 216 of the student textbook do correctly show the details of the refraction taking place twice for each type of lens.
- Some students may confuse the properties of lenses with mirrors. Concave mirrors converge light rays, while concave lenses diverge them. Also, mirrors reflect light, whereas lenses refract light. Convex mirrors diverge light rays, while convex lenses converge them. That is, concave mirrors and concave lenses behave oppositely, just as do convex mirrors and convex lenses. Students may find it helpful to think of the marching band image, illustrated in Section 5.1, to help them decide what will happen to light rays passing through each interface on each type of lens.

ADVANCE PREPARATION

- For Find Out Activity 6-1A, Lenses and Light Rays, on page 215 of the student textbook, you will need ray boxes, and concave and convex lenses. You may need to order and purchase these materials a month before completing the activity.
- For Find Out Activity 6-1B, The Focal Length of a Convex Lens, on page 218 of the student textbook, you will need convex lenses.
- For Find Out Activity 6-1C, Make a Model of a Projector, on page 224 of the student textbook, you will need convex lenses and unfrosted light bulbs. You may need to purchase the light bulbs a few days before completing the activity.
- For Conduct an Investigation 6-1D, Pinhole Camera, on page 225 of the student textbook, you will need tubes of different diameters (from wrapping paper, paper towels, etc.) and adhesive tape with a frosty appearance. You may want to tell students to start collecting these items from home one month before completing the activity.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, pp. 214–215

Using the Text

Read aloud the introductory paragraph on page 214. Ask students to list other examples of objects that contain lenses. Ask, “What purpose do the lenses serve?” Have students examine Figure 6.2 on page 215. Ask them to describe the appearance of objects seen through the lens compared to the objects themselves. How are they similar? How are they different?

The discussion will provide a natural lead-in to the next section on the characteristics of images formed by convex and concave lenses.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-7 and 2-8, Chapter 6 Key Terms, can be used to assist students.

Using the Activity

Find Out Activity 6-1A

Lenses and Light Rays, p. 215

Purpose

- Using a ray box, students observe light rays refracting as they pass through a lens.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For each group: – ray box – concave lens – convex lens – printed page

Time Required

- 20 min

Safety Precautions

- Caution students that lenses are fragile and can break easily.
- Students should be careful not to bang or drop the ray box.
- Remind students that the area near the bulb of the ray box becomes hot after use; students should not touch it.

Science Background

Concave lenses diverge light, so images appear smaller than the objects. Convex lenses converge light but the image may appear larger or smaller depending on how far away the object is from the lens.

Activity Notes

- Although the procedure suggests that the ray box should be used first and then the lens should be looked through, it is best if students go back and forth between using the ray box and looking at the lens until they get a feel for how lenses affect light.
- Summarize the activity by comparing each group's results when passing light from a ray box through a convex, and then a concave, lens. They should all have found that a convex lens made the rays converge, and a concave lens made the rays diverge.

Supporting Diverse Student Needs

- Before students begin, help students with reading difficulties follow the steps in What to Do by demonstrating the set-up of the apparatus using a flat piece of glass (so as to not give results away).
- Students could answer What Did You Find Out? question 1 using a diagram, or a pair of diagrams, instead of providing a written comparison. For What Did You Find Out? question 3, students could brainstorm answers in a group, then choose an answer to record from among the groups' answers.
- For enrichment, ask students to devise a way to use the results of this activity to predict what would happen if light were shone through two convex lenses.

What Did You Find Out? Answers

1. The convex lens will magnify the print, provided the object is not placed beyond 2F, while the concave lens will shrink the print image.
2. A convex lens should be used as a magnifying glass because images cast through it look larger than they really are.
3. Students' answers could include the concave lens being used to get a wide-angle view, such as with a peephole in a door or the viewfinder in a camera.

Using a Demonstration

To model how eyeglasses help with focussing, use an overhead projector to project an image of text or a drawing on a large screen. Then adjust the projector until the image is out of focus. Now, hold a pair of glasses in the beam of the projector and move them closer to or farther from the screen in order to bring a part of the image back into focus. This process demonstrates the power of corrective lenses. Alternatively, you may use different convex and concave lenses to show the effects of each type of lens.

TEACHING THE SECTION, pp. 215–223

Using Reading

Pre-reading—Predict-Read-Verify

Break up the section into manageable chunks for students. Some suggested chunks are the following:

- Refraction of Light Through Lenses
- Convex Lenses
- Concave Lenses

Ask students to read the titles and look at the diagrams to make a prediction about what each chunk will be about. Upon reading the student textbook, ask students to compare or verify their predictions with what they learned.

During Reading—Note Taking

Encourage students to take notes as they read through each chunk. They can rewrite the topic titles in the form of questions to which they will find the answers as they read the section. For example, "Where does refraction take place in a lens?" "What are the two types of lenses?" "What are the image characteristics of each lens?"

Supporting Diverse Student Needs

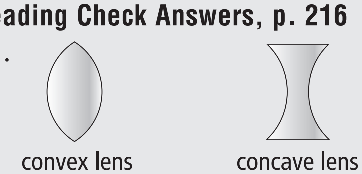
- Students can draw their ray diagrams on BLM 2-37, Concave Lens Template, and BLM 2-38, Convex Lens Template.

After Reading—Semantic Mapping

Have students review their notes and summarize them in one Venn Diagram and two flow charts—the Venn diagram to compare and contrast convex and concave lenses; one flow chart to sequence the steps for drawing ray diagrams for a convex lens, and one flow chart to sequence those steps for a concave lens. Students can summarize what they have learned using BLM 2-39, Lenses and Light.

Reading Check Answers, p. 216

1.

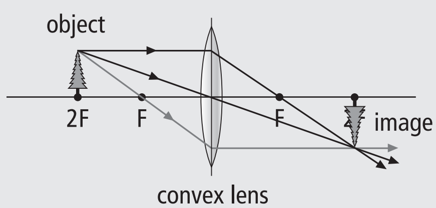


2. When two parallel rays pass from air into a concave lens, the normals to the surface at which they enter are at different angles from each other, so the light rays themselves will bend at different angles. Refer students to Figure 6.4 (B) on page 216 of the student textbook.

3. A concave lens makes parallel rays spread apart (diverge).

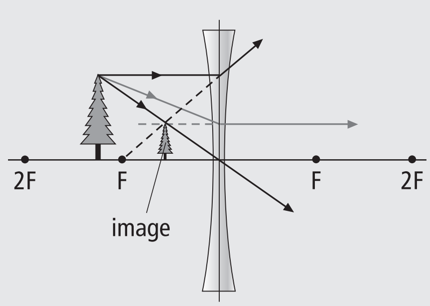
Reading Check Answers, p. 221

1. The focal point of a convex lens is where the parallel light rays meet after passing through the lens.
2. The amount of curvature on a convex lens determines the location of the focal point. The greater the curvature, the closer the focal point is to the lens. The shorter the curvature, the farther the focal point is from the lens.
3. A lens has two focal points because you can shine light on either side of the lens.
4. The image characteristics of an object that is exactly two focal lengths from a convex mirror are the following:
   - same size as the object
   - same distance from lens
   - inverted
   - real



Reading Check Answers, p. 223

1. In order to find the focal point of a concave lens, extend the refracted rays backward to the point at which they will meet.
2. The curvature of a concave lens determines the location of the focal point. The greater the curvature, the closer the focal point is to the lens. The smaller the curvature, the farther the focal point is from the lens.
3.



The characteristics of the image include the following:
- The image is smaller than the object.
- The image is closer to the lens than the object.
- The image is upright.
- The image is virtual.

USING THE ACTIVITIES

- Activity 6-1A on page 215 introduces students to the effects of light rays passing through different types of lenses. A full description of Activity 6-1A can be found in Introducing the Section.
- Activity 6-1B on page 218 of the student textbook is best used after students have read and discussed the section on focal length in convex lenses.
- Activity 6-1C on page 224 of the student textbook is best used after students have read the section on convex lenses.
- Activity 6-1D on page 225 of the student textbook is best used after students have read the section on using ray diagrams to predict image characteristics in a convex lens.
- Detailed notes on doing the activities follow.

Find Out Activity 6-1B

The Focal Length of a Convex Lens, p. 218

Purpose
- Through investigating, students find the focal length of a convex lens.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For each pair: – convex lens – ruler – masking tape – stiff white paper

Time Required
- 10 min

Safety Precautions
- Caution students that the lenses are fragile and can break easily.
- Instruct students never to direct the sunlight into someone's eyes.

Science Background

The focal length of a lens is the distance between the focal point of the lens and the centre of the lens itself. The focal length is important in determining where an image will be formed.

Activity Notes
- Have students work in pairs—one can hold the

ruler steady while the other moves the paper back and forth until the image comes into view. The paper should be held parallel to the lens.
- If students find it difficult to locate the spot of sunlight on the piece of paper, an alternative is to focus on a distant object outside the window, such as a tree. The image of the tree should appear on the paper if it is placed at the focal point of the convex lens.

Supporting Diverse Student Needs
- What Did You Find Out? questions 1 and 3 can be answered by drawing and labelling diagrams, as an alternative to writing.
- For enrichment, have students find the focal lengths of convex lenses with different curvatures. In this way, students will observe how curvature changes the location of the focal point, as discussed in the student textbook on page 217.

What Did You Find Out? Answers
1. Students' answers will vary, depending on the curvature of the convex lens.
2. The distance measured is the focal length of the lens because that is where all the parallel light rays converged to form an image after passing through the lens.
3. Students' answers will vary, depending on whether the convex lens has the same curvature on both sides. If it does, then the focal point on the other side of the lens would be the same distance from the lens.

Find Out Activity 6-1C
Make a Model of a Projector, p. 224

Purpose
- Students investigate how a lens can be used to magnify and project an image.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
A few days before 1 day before	Purchase unfrosted light bulbs. Gather materials. Make copies of BLM 2-40, Projector Arrows.	For each group: – sheet of paper – felt pen – beaker – water – convex lens – unfrosted light bulb (and sockets connected to power source) – BLM 2-33, Projector Arrows

Time Required
- 25 min

Safety Precautions
- Caution students that lenses are fragile and can break easily.
- Caution students to keep the electrical cord from becoming wet.
- Remind students that the light bulb becomes hot very quickly.

Science Background
The beaker will act like a convex lens (since its shape is curved outward) and the arrows will be magnified. If the beaker is passed from left to right in front of the arrows, the arrows will appear to move from right to left. This result is similar to what happens when a transparency of printed text is placed onto an overhead projector. When the sheet of transparency is moved in one direction, the resulting image on the screen moves in the opposite direction.

Activity Notes
- Have students work in small groups of three or four.
- A set of arrows to use in the activity can be found on BLM 2-40, Projector Arrows.
- Students will need sockets connected to a power source to use their light bulbs.
- The convex lens will project an image of the filament in the unfrosted light bulb. The image can be brought into focus by moving the lens back and forth until the correct location has been found.
- You could demonstrate how an overhead projector affects rays of light to show the similarities between it and the beaker of water.

Supporting Diverse Student Needs
- Pair students who have reading difficulties with confident and competent readers to ensure understanding of the What Did You Find Out? questions.
- A quick demonstration of both parts of the activity—viewing the arrows and the light bulb—will help ensure everyone understands the instructions.

What Did You Find Out? Answers
1. (a) If the paper was held close to the beaker of water, the image had the same orientation up and down and side to side. If the paper was held far from the beaker, the image had the same orientation up and down, but reversed orientation side to side. (This result is because the beaker is cylindrical and convex side to side, so it only acts as a convex lens only in that direction.)
   (b) If the paper was held close to the beaker of water, the image was larger. If the paper was held far from the beaker, the image was smaller.

2. (a) The projected image of the filament is reversed side to side as well as inverted top to bottom.
   (b) The projected image of the filament could be larger or smaller than the actual filament depending on the distance the light bulb is from the lens. If the light bulb is between the focal point and twice the focal length, then the image of the filament will be larger than the actual filament. If the light bulb is more than twice as far from the lens as the focal point, then the image of the filament will be smaller than the actual filament.
3. The beaker of water is like a double convex lens because the round shape of the beaker can be thought of as two semicircular convex lenses placed back to back.

Conduct an Investigation 6-1D

Pinhole Camera, p. 225

Purpose

- Through investigating, students discover how a tiny hole can act like a lens.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 month before	Ask students to collect tubes of different diameters (from wrapping paper, paper towels, etc.).	For each group: – 2 tubes of different diameters or make 2 tubes using tape and paper – adhesive tape (with frosty appearance, not clear) – scissors – aluminum foil – pushpin
1 day before	Gather materials.	

Time Required

- 20 min

Safety Precautions

- Remind students to be careful with scissors.
- Tell students to never look directly at the Sun with any camera, including the one constructed in this activity.

Science Background

The pinhole camera uses a tiny hole in an opaque material (aluminum foil) to behave as a lens by restricting the amount of light entering the camera. In this way, a clear image can be projected onto the screen (frosted adhesive tape). The best holes are completely round. They need to be small enough to block any stray light, but not so small as to cause interference effects (fringes) that will happen because light is a wave and interferes with itself. The image will be faint because the hole is so small, so this activity works best with bright lights.

Activity Notes

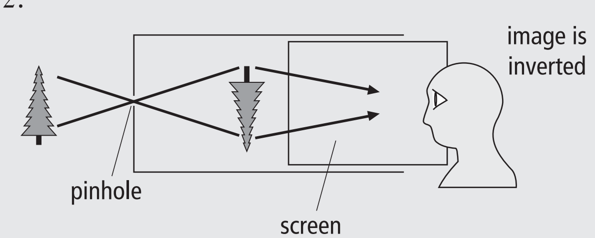
- Completely round holes make the best images.
- Tubes can be made out of paper. Roll one sheet into a cylinder and tape it. Cover one end with frosted adhesive tape (without collapsing the tube). Then roll a second sheet of paper around the first tube and tape the second sheet so that it can slide easily on the first tube. Put aluminum foil on one end of the outside tube (the same end of the camera as the adhesive tape).
- View a bright object such as a light bulb or a television screen. The image will appear on the frosted adhesive tape, which acts like a transparent screen.

Supporting Diverse Student Needs

- You may need to demonstrate how the two tubes are made to help students with reading difficulties follow the instructions.
- To encourage creative thought, students could consider their own answers to Conclude and Apply, then discuss them with a classmate, before they record an answer.
- For enrichment, have students enlarge the pinhole a little at a time to investigate the effect of the size of the hole on the image that is produced.

Analyze Answers

1. The letter *d* would appear as the letter *p*, since the image is reversed left to right and inverted.
2.



Conclude and Apply Answers

1. Tiny holes in the leaves can act like pinholes to cast images of the Sun onto the ground.

USING THE FEATURE

www Science: Gravitational Lenses, p. 226

An interesting way to end the section on lenses is by discussing the largest kind of lenses known to exist. A discussion of gravitational lenses is also a good way to reinforce the fact that what makes something a lens is not what it is made of, but what it does to light. You might ask students whether gravitational lenses really are lenses (they are, since they can converge light), or what kind of glass lens they are analogous to (convex lenses, which also cause convergence).

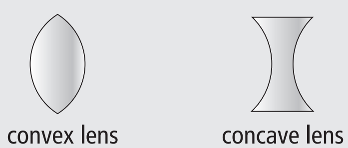
A gravitational lens is formed when the light from a very distant bright source "bends" around a massive object due to gravity and comes together at one point. The massive object in this case is a cluster of galaxies. This bending of the paths followed by light rays can magnify and distort the apparent image of source objects found behind the gravitational lens. If the source object, gravitational lens (bright galaxy), and observer lie in a straight line, the source object may appear as a ring behind the lens. This result is known as an Einstein ring. If the source object happens to be the same distance behind the gravitational lens as the observer is in front, then the source object will appear as two images on either side of the lens (see the diagram on page 226 in the student textbook).

SECTION 6.1 ASSESSMENT, p. 227

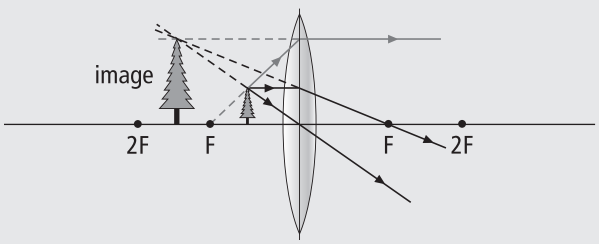
Check Your Understanding Answers

Checking Concepts

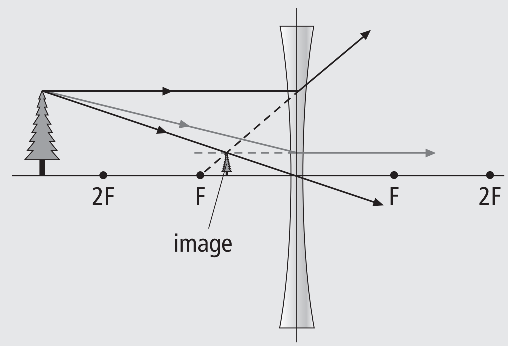
1.



2. A concave lens causes parallel light rays to diverge.
3. Lenses have two focal points because you can shine light on either side of the lens.
4. A convex lens should be used in a magnifying glass because images cast through it can look larger than they really are. Images seen through a concave lens are always smaller.
5. The location of the focal point of a convex lens depends on its curvature. The greater the curvature of the lens, the closer the focal point is to the lens.
6.



The image is larger than the object, farther from the lens than the object, upright, and virtual.



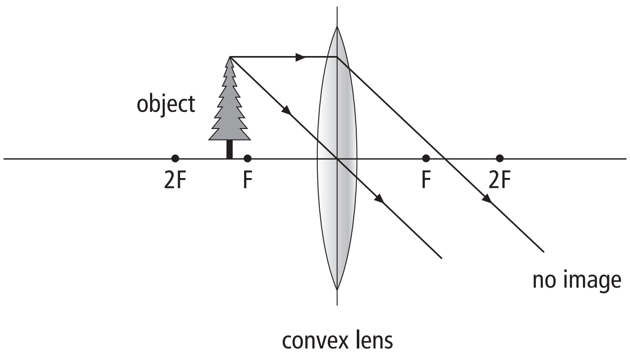
The image is smaller than the object, closer to the lens than the object, upright, and virtual.

Understanding Key Ideas

7. A concave lens affects light more like a convex mirror because both cause parallel light rays to diverge.
8. The first ray is drawn parallel to the principal axis until it meets the centre of the lens, where the refracted ray travels through the focal point on the opposite side of the lens. The second ray passes through the near focal point, and the refracted ray runs parallel to the principal axis. The third ray travels straight through the optical centre and the refracted ray continues in a straight line on the other side of the lens. For an object between the focal point and the lens, these rays will need to be extended backward to the point where they meet to find the image.
9. A convex lens will not produce a magnified image of the object if the object is located more than twice as far from the lens as the focal point.
10. The image produced by a concave lens is always virtual. That is, the image is always located on the same side of the lens as the object.

Pause and Reflect Answer

If the object is exactly on the focal point of a convex lens, no image will form. The ray that passes through the near focal point to the lens cannot be drawn, and the other two rays refract parallel to each other.



Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

6.2 HUMAN VISION

BACKGROUND INFORMATION

In this section, students will take a close look at the anatomy of the human eye, and learn how light rays are captured through the pupil, screened by the iris, focussed by the cornea and lens, and detected at the retina. There are a number of interesting features in the human eye, including the way in which the image is cast upside down on the retina, as well as the existence of a blind spot in each eye.

In previous sections, students saw that an object placed in front of a lens would create an image only at a fixed location. Muscles in the human eye can relax or contract to change the shape of our eye's lens. So, the lens of the human eye is able to focus light rays so that no matter where an object is, its image falls on the retina. In some cases, corrective lenses are necessary to help with this process.

Making sense of the detected light is the job of the brain and the retina. The retina contains rod cells and cone cells. Light detection by rod cells is more efficient than by cone cells for two main reasons: 1) We have more rod cells (100 million rods and 7 million cones per eye), and they are more sensitive, becoming stimulated at a lower intensity of incident light. The rod cells are responsible for determining shapes, movement, and shades of grey, while the cone cells detect colour. These cells then convert the light into electrical signals that are sent to the brain through a thick nerve called the optic nerve.

Humans are trichromatic, meaning we have three types of cone cells, and our retinas are wired to keep track of these colours and send three separate colour signals to our brain, which combines them as needed. Thus, human vision is a complex process, involving systems and subsystems that operate without our consciousness.

COMMON MISCONCEPTIONS

- Some students may believe that focussing is done exclusively by the lens. In fact, the cornea does 70% of the focussing, while the lens provides variation in focussing so that we can see both near and far.
- Some students may believe that our eyes relax to see close objects and strain to see far away. In fact, it is the other way around. There is a ring of muscles that surround the lens. When the muscles relax, the ring gets larger, which pulls on the lens. This pulling action creates tension that makes the lens thinner, which is actually good for focussing on distant objects. When the muscles contract, the ring gets smaller, which releases the tension on the lens, makes its curvature greater, and helps to focus on close objects.

ADVANCE PREPARATION

- For Conduct an Investigation 6-2D, Dissecting a Sheep Eye, on pages 238 and 239 of the student textbook, you will need preserved sheep eyes, prods, dissection trays, and protective gloves for each group. You may need to order the sheep eyes several weeks in advance.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 228

Using the Text

Read aloud the introductory paragraph. You may wish to start a discussion on the importance of sight as the primary sense (compared to hearing, touch, smell, and taste) that enables us to carry out many of our daily activities.

Our eyes are made up of living cells that work together to allow us to see objects near and far, in colour as well as in shades of grey. The cells of the cornea are transparent, yet they are alive and they do need nutrients. Some of the oxygen they need comes directly from the air. The tear ducts produce a liquid that is very complex and contains many chemicals that can lubricate and clean the surface of our eyes. These chemicals can kill bacteria, and as such, the liquid is part of our immune system. Our eyes are certainly a unique part of us, and in this chapter, students will take a close look at the anatomy of the human eye.

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-7 and 2-8, Chapter 6 Key Terms, can be used to assist students.

Using the Activity

Find Out Activity 6-2A

Changing Colours, p. 228

Purpose

- Through investigating, students observe how colour vision adapts to changing light conditions.

Time Required

- 5 min

Science Background

Many people will say that the colour of objects in a room remains the same even though the lighting changes from daylight to artificial light at night. Our vision adapts to different lighting conditions automatically.

When we stare at a solid colour for a while, a kind of fatigue sets in, and we become less sensitive to that colour. This activity is a good example of this effect. When students stare at the picture of the Canadian flag, its image is projected onto the retina, where the blue and green cones react strongly to the bluish-green tint for the duration of the stare, while the red cones do not. This reaction fatigues the blue and green cones. So, when students are asked to switch their gaze to look at a white space on the page, the red cones will react strongly while the blue and green cones relax. This reaction produces an afterimage of the flag in its normal colours (red and white). The black part of the flag gives the cone cells a rest and the white page appears brighter white than it otherwise would. After a few seconds, the image of the Canadian flag will fade.

Activity Notes

- This activity needs some patience. A sufficient amount of time must be spent on staring at the flag without moving the eyes (at least 30 s to 1 min) in order to achieve the effect of colour fatigue.
- Instead of looking at a white space on the page, it might be easier for students to look at a separate sheet of white paper (where there is no other text or visuals to distract their eyes).

Supporting Diverse Student Needs

- For students with colour vision deficiency or colour blindness, the resulting afterimage will not be the normal red and white colours of the Canadian flag. These students can share with the class what they do see and the discussion can be used as a lead-in to the section about colour vision.
- Discussing students' answers to What Did You Find Out? questions 1 (a) and (b) will help students who may not have obtained the same results, or who may not have thought of a reason for them, develop their answers to question 2.
- For enrichment, have students use crayons or markers to create their own versions of this visual effect. They can trade their drawings with another student, who will predict what the after image will look like before testing it out.

What Did You Find Out? Answers

1. (a) If the effect works for the viewer, the Canadian flag will appear in its normal red and white colours.
   (b) The eye adapts to the colour it is looking at by becoming less sensitive to it. When looking at a white page, which contains all the colours, the other colours are detected more readily.
2. As lighting conditions change between bright sunlight and twilight, the sensitivity of the colour vision increases to allow a scene to continue to be viewed with comfort.

Using a Demonstration

Use a variety of optical illusions to demonstrate that vision and perception are interesting and complex processes. There are many examples easily obtainable on the Internet.

TEACHING THE SECTION, pp. 229–236

Using Reading

Pre-reading—Key Word Concept Maps

Key word concept maps help students broaden their understanding of key word concepts. Before reading, teach the terms “cornea,” “retina,” “cone cells,” “rod cells,” “far-sighted,” “near-sighted,” and “colour blindness.” During reading, students can link these terms to the text by taking notes. After reading, students can identify word concepts they wish to learn more about.

Supporting Diverse Student Needs

- Understanding the ideas in this section is dependent on knowing the meaning of these key words. Tell students that if they encounter one of these words as they read and are unable to remember its meaning, they should look it up in the glossary, or on one of the diagrams in this section of the textbook.

During Reading—GIST

Have students read the text under each section heading and summarize the ideas presented in the text. Challenge students to reduce each passage to just 20 words that capture the gist of the text.

After Reading—Reflect and Evaluate

Have students review their notes and choose three facts that they find most interesting. They can then write a statement as to why they found these facts to be interesting and propose further research they may conduct for future learning. If you wish to emphasize the role the brain plays in interpreting the data it receives from the eye, use BLM 2-41, Optical Illusions.

Reading Check Answers, p. 231

1. Light rays passing through the pupil have already moved through the cornea and some watery fluid. They then move through the lens, more watery fluid, and finally fall onto the retina, where they are absorbed.
2. Most of the focussing in the eye is done by the cornea.
3. The lens becomes thicker when the eye is focussing on objects that are close.
4. The lens becomes thinner when the eye is focussing on objects that are distant.
5. The focal point of the lens is inside the middle of the eye, in the watery fluid. At this point, all light rays come to one point, and then begin to diverge. This process causes the crossover of light rays that results in an inverted image when it strikes the retina.

Reading Check Answers, p. 236

1. As children grow, different parts of the eye can change shape at different rates and temporarily make it more difficult to focus. As people age, the lens begins to harden, making it more difficult to become thicker. This result makes it more difficult to see close objects.
2. The eye of a person who is near-sighted causes light rays to converge too soon, forming an image in front of the retina instead of on it. This result makes it especially difficult to focus on distant objects because the light from them is almost parallel when it enters the eye and needs the least amount of converging. Light rays from nearby objects are diverging as they enter the eye and need the most amount of converging to bring them into focus. This process is easy for a person who is near-sighted.
3. The eye of a person who is far-sighted cannot cause light rays to converge enough, and an image is formed behind the retina instead of on it. This result makes it especially difficult to focus on nearby objects because the light from them is diverging when it enters the eye and needs the most amount of converging. Light rays from distant objects are nearly parallel as they enter the eye and need the least amount of converging to bring them into focus. This process is easy for a person who is far-sighted.
4. Astigmatism is the formation of multiple blurry images instead of a single clear one. It is caused by an irregularly-shaped cornea which causes light to be focussed in several places at one time.
5. A person who is legally blind might see clearly only in a tiny part of the middle of a whole scene, or see on the edges of their vision (but not in the centre). Others can detect only light and darkness.
6. Malnutrition and lack of vision care can both cause blindness. These types of vision problems tend to affect people who are financially disadvantaged, or people without vision clinics nearby, such as children in developing countries.
7. Snow blindness can be prevented with the use of close-fitting sunglasses or goggles with only thin slits.

USING THE ACTIVITIES

- Activity 6-2A on page 228 introduces some of the complex aspects of the way our eyes work.

Detailed notes about this activity are provided in Introducing the Section.

- Activity 6-2B on page 233 of the student textbook is best used after students have read page 232. The activity will give students the opportunity to compare and contrast the function of the rod and cone cells.
- Activity 6-2C on page 237 of the student textbook is best used after students have read the section about types of blindness on page 236.
- Activity 6-2D on pages 238 and 239 of the student textbook is a dissection of a sheep eye, and will support lessons on the anatomy of the eye with a hands-on approach. It can be used anytime after students have read to the end of page 231.
- Detailed notes on doing the activities follow.

Think About It Activity 6-2B

What Colours Do Rod and Cone Cells Detect?, p. 233

Purpose

- By analyzing information in a chart and graph, students compare and contrast the structure and function of rod and cone cells.

Time Required

- 20 min

Science Background

The names "rod" and "cone" reflect the general shape of each cell. Rod cells are cylindrical in shape and are located at the outer edges of the retina. They are about 100 times more sensitive to a single photon of light than cone cells, so are well adapted for night vision. Cone cells have a cone-like shape, function better in bright light conditions, and are responsible for colour perception.

Rod cells respond to low levels of light at all wavelengths of the visible spectrum, while the different types of cone cells are responsible for detecting different ranges of wavelengths. Although we refer to the cone cells as being able to detect the three primary colours of light (blue, green, and red), they can actually detect light covering a wide variety of wavelengths and colours. For example, the cone cells that detect blue light not only detect blue, but can detect light that has wavelengths in the blue-violet range of the visible spectrum. The ranges of colour detected by the three types of cone cells overlap, and our brain uses the input of information from all three types of cone cells to determine what colour we actually perceive.

Activity Notes

- Have students read page 232 before doing the activity. They can work individually or with one partner.
- Part 1 is a reading activity. Students are given more information than is necessary to answer questions 2 and 3, and they must choose the most relevant parts to put into a coherent answer.
- In Part 2, students might need some explanation and practice in reading the graph. Discuss question 5 (a) and (b) orally with students, but instead of using "R," use "B" for blue sensitive cells. No questions in the report are asked about the "B" line. This omission enables you to teach how to use the graph without giving away all the answers.

Supporting Diverse Student Needs

- Students who have difficulty with the writing process could answer Part 1 in point form, taking points directly from the table. If you model the process of using the information in the table by answering question 2 then question 3 could be used as a practice exercise for students.
- Students with perceptual difficulties may benefit from holding a ruler on top of the graph in Part 2 to help them line up data points with corresponding values on the axes.
- For enrichment, students could combine information from the graph in part 2 with Figure 4.21 on page 150. For example, students could name the colours that the red sensitive cones can actually detect.

What to Do Answers

Part 1

2. Rod cells are more useful for night vision because they are very sensitive to all light. Their greater amount of pigment allows them to detect light even at a very low level.
3. Cone cells are more useful for colour vision because they have three types of pigments. The three types allow different colours to be perceived separately from one another.

Part 2

5. (a) Red-sensitive cone cells detect most effectively at about 560 nm (their sensitivity peaks at 564 nm).
   (b) You might wish to refer students to page 150, Figure 4.21 in the student textbook. Green/yellow corresponds to 560 nm.
   (c) The red-sensitive cone cells can actually detect green better than red.

(d) The red-sensitive cone cells are better at detecting red than either of the other two kinds of cones.

6. (a) Black- and white-sensitive rod cells detect most efficiently at about 490 nm (they peak at 498 nm).
   (b) Refer to page 150, Figure 4.21 in the student textbook. The wavelength 490 nm corresponds to green.
7. Humans are able to detect faint amounts of green light for two reasons: Rod cells are the most sensitive kind of light-detecting cells and their pigment is more efficient at detecting green. Also, all three types of cone cells are able to detect some green light.

Think About It Activity 6-2C

Being Blind, p. 237

Purpose

- Students learn about the life of a blind student.

Time Required

- 15 min

Science Background

Language is not dependent on any one sense. Children who are deaf may learn only sign and written language; children who are blind learn Braille and spoken language; and children who are both deaf and blind may learn only Braille and have none of the deficits of children who grow up without any language at all. It seems that what we see or hear or feel with our fingers, or sign with our hands, stimulates the same places in the brain that develop language.

Activity Notes

- A unit on optics and vision might be frustrating to a person who is blind. This activity, adapted with permission from a brochure by the Canadian National Institute for the Blind, gives a perspective that a person who is blind might have.

Supporting Diverse Student Needs

- If some students in your class have reading difficulties, read the letter from Sean aloud to the class.
- Students who are blind or who are visually impaired will certainly have their own opinions on what sort of language they like to use. They may also have ideas about the requirements they need to function in an integrated classroom. Provided they wish to share their feelings, they may be able to add further perspectives on the topic.

What Did You Find Out? Answers

1. (a) Many people with vision impairment do not mind the use of words such as “see” and “watch” in everyday speech with their friends. If in doubt, just ask the person.
   (b) Phrases such as “The book is over there” or “Come here” are meaningless to anyone who is blind. Instead, details of the specific location should be given.
2. Students’ answers could include the following: A person who is visually impaired and who is new to the classroom would like to feel accepted and included in the class. You might begin by simply remembering to include and talk with him/her.
3. Students’ answers could include the following: People who are blind need to know where things are, so not moving objects around would be helpful. Also, it is important not to block walkways with items such as backpacks.

Conduct an Investigation 6-2D

Dissecting a Sheep Eye, pp. 238–239

Purpose

- Students examine a sheep eye and compare and contrast its anatomy with a human eye.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
Several weeks before	Order the sheep eyes, as well as the dissection equipment if necessary.	For each group: – preserved sheep eye – scissors – prod – dissection tray – protective gloves – paper towels – plastic disposal bag – 10 percent bleach solution
1 day before	Gather materials. Prepare 10 percent bleach solution.	

Time Required

- 45 min

Safety Precautions

- Students should wear protective gloves. Provide instructions for disposing of the gloves after the activity.
- The sheep eye is raw meat. Make sure students wash their hands with soap after completing the dissection to ensure that all bacteria have been washed off.
- Instruct students to keep their hands away from their eyes and mouth when handling the sheep eye.

- Ensure that all of the animal parts are cleaned up and discarded according to your instructions.
- Sharp edges can cut. Advise students to be careful with scissors and prods.

Science Background

The sheep eye used in the dissection was obtained from a sheep that was slaughtered for food. It will come packed in a preservative. Formaldehyde is no longer used because it is carcinogenic. Current preservatives use alcohol as well as other chemicals. They can be washed down the sink when the sheep eyes are rinsed to remove the preservative just before use.

Activity Notes

- Students can work in pairs or groups of three.
- Be aware that some students may have latex allergies. Pair these students with those who can do the dissecting while they observe and take notes.
- Students will find that the sclera is indeed very tough when they cut into it.
- Wash up using soap. Remove the discarded tissues and wash out the dissecting trays as soon as possible after use.
- Ensure that students remove their gloves before leaving their work area after they have done the bleach clean-up. They should remove each glove by grasping the end closest to their wrist and pulling it toward their fingertips, turning the glove inside out as they go.

Supporting Diverse Student Needs

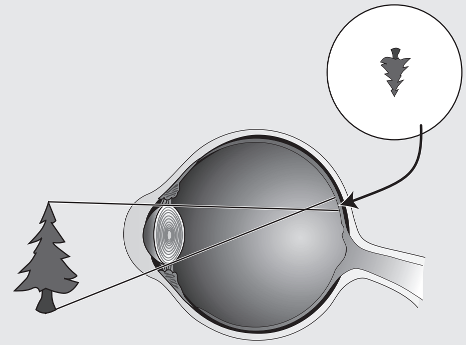
- It can be difficult for some students to make connections between the descriptions they read and what they see in the actual eye. Let them know that if they ever are unsure that they are looking at the right part of the eye, they can ask for you to come over and confirm, or redirect them.
- Conscientious objectors or the very squeamish may wish to give this activity a pass. However, they can watch a partner do the dissection.

Analyze Answers

1. Students' answers could include the following:

SHEEP EYE	HUMAN EYE
4 muscles to move eye	6 muscles to move eye
oval iris	circular iris
Iridescent layer under retina	No iridescent layer
No black layer under retina	Black layer under retina

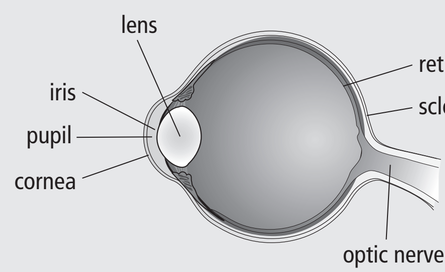
2. The image cast on the retina is inverted.



3. The lens from the sheep eye may be hard, yellow, spherical or oval, smooth, and translucent.

Conclude and Apply Answers

1. Students' diagram should include the cornea, sclera, iris, pupil, lens, optic nerve, and retina.



2. Students' answers could include the following: Since processing of electrical signals begins right in the retina, it can be argued that the retina is an extension of the brain.

USING THE FEATURES

Did You Know, p. 229

One of the main factors that have affected the evolution of colour perception in animals is the recognition of food sources necessary for survival. In herbivorous animals, for example, colour perception is important for finding mature plants and leaves. In primates, trichromatic colour vision developed as the ancestors of modern monkeys and humans began to consume fruits and leaves. Considering the amount of green in our environment, it is not surprising that we evolved a strong sensitivity to the colour green. This result does not mean that we perceive greens as brighter than other colours, but it means that if you wish to make a green light and red light equally visible to a distant observer, more energy is needed to light the red light than the green light.

www Science: Can You See What I Hear?, p. 240

Human echolocation is the ability of humans to sense objects in their environment by listening to echoes that bounce off those objects. Some blind people use echolocation to navigate themselves in their environment. They create sounds, such as tapping their canes or by making clicking sounds with their tongue, then listen for the echoes that help identify the location of nearby objects. The text in the first paragraph of this reading feature suggests an interesting activity that can be done as a class demonstration. The remainder of the feature shows how the tremendous advances in miniaturization of electronic video and audio components can be put together in novel and useful ways.

SECTION 6.2 ASSESSMENT, p. 241

Check Your Understanding Answers

Checking Concepts

1. Students' answers could include the following:

PART OF EYE	FUNCTION
Sclera	Surrounds and protects eye
Cornea	Protective outer surface; focussing
Pupil	Opening that allows light to pass through
Iris	Controls the amount of light entering eye
Lens	Focussing
Retina	Detects light; where image is formed
Optic nerve	Carries light signals from retina to brain

2. (a) The cornea and the lens are involved in focussing an image.
   (b) The cornea does most of the focussing, but the amount of focussing is not adjustable. The lens does less focusing, but it can be adjusted (fine tuned) to bring the image into focus.
3. (a) The vision problem shown by the illustration is near-sightedness, because the image forms in front of the retina instead of on it.
   (b) Corrective concave lenses can be used to help with this problem.
4. The human colour vision system needs bright light to become activated. This result means colour is seen better in bright light.
5. Students' answers could include the following: Blindness is any long term impairment that does not allow a person to see.

Understanding Key Ideas

6. If a person's lens was unable to change shape, then that person could not focus on objects located at different distances, but instead, would be able to see clearly at only one distance.
7. All three kinds of cone cells are necessary to detect the three primary colours needed to construct all the colours.
8. (a) In sudden brightness, the iris contracts the pupil, reducing the amount of light striking the retina.
   (b) In gradual dimming of light, the muscles of the iris dilate or enlarge the pupil, letting in more light.
   (c) Looking at a kite, the eye is focussing at a distant object by relaxing muscles in the eye, which causes the lens to become thinner. Looking down at your hand, the muscles tighten up, which causes the lens to thicken, allowing the close object to come into focus.
9. Students' answers could include the following: It is difficult to know for sure whether animals can see colour, or which colours they are able to see. If they did not have cones in their retina, then they could not see colour. If they had only one type of cone or two types of cones, then they could see only a few colours.

Pause and Reflect Answer

Students' answers could include the following:

- Treat malnutrition generally, and more specifically; ensure an affordable supply of vitamins that promote good vision (such as vitamin A) is available.
- Subsidize the production and distribution of eyewear.
- Promote education and training of vision health professionals.
- Promote early testing of children for vision problems.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

6.3 EXTENDING HUMAN VISION

BACKGROUND INFORMATION

This section introduces microscopes, telescopes, binoculars, and cameras. Features common to all of these optical devices are highlighted, as well as a few points that make each device distinct from the others. Essentially, all of these devices are based on arrangements of lenses and/or mirrors to manipulate light rays and create an enhanced image of an object. Details of each device are shown in diagrams in the student textbook.

The section culminates with a comparison between a camera and a human eye. Any of the other three devices would also make interesting comparisons with the eye, and such an exercise would be an interesting way to engage students in the learning process. Similarly, differentiating between reflecting and refracting telescopes, or comparing and contrasting a telescope with a microscope, would give students something interesting to think about. Some hints of these comparisons appear in the student textbook.

This section connects basic properties of light, mirrors, and lenses to some of their very practical applications. When teaching about the optical devices, a good strategy is to emphasize how we use scientific knowledge to produce instruments that advance our society.

COMMON MISCONCEPTIONS

- Some students may believe that microscopes and telescopes are fundamentally different because they have different applications. Yet from another point of view, these differences are small. There is a difference in the distance to the object being studied, but both devices collect rays from an object and use lenses and mirrors to manipulate the rays to form a magnified image.
- Some students may believe that telescopes, microscopes, and even cameras are so complex as to be beyond comprehension. On the contrary, the important principles on which these devices are built have already been studied earlier in the unit. For example, the optical system in the Hubble Space Telescope employs a series of mirrors that work on the basic principles of light and reflection—concepts that have been studied in a previous chapter. Yes, the technology may be complex, but the underlying principles are straightforward. Helping students realize this distinction is good practice and will help develop scientific literacy.

ADVANCE PREPARATION

- For Think About It Activity 6-3B, Microscopes on the Job, on page 244 of the student textbook, students will need to conduct research on the Internet or at the library. You may need to book the computer lab or library time in advance.
- Consult the Unit front matter for a list of BLMs that can be used when teaching this section.

INTRODUCING THE SECTION, p. 242

Using the Text

The opening paragraph on page 242 directs students to reflect on two very different images: the tiny world of micro-organisms and the vast expanse of outer space. The essential difference between the two images is scale. Technology has made it possible to study and better understand these two opposite extremes of our universe. As a class, compile a list of things that are the same and different about these worlds. For example, you can see both the microscopic world and outer space better with magnification, and you can use what you see to learn about the environment and to develop useful technologies. For the microscopic world, you need to collect samples to examine. For outer space, you need to observe at a specific time.

Students often ask, "How do *they* know this?" The main pedagogical task in completing this optics unit may be to convince students to change the question to, "How do *we* know?" and to help students feel that they are part of the "we."

Using the Key Terms and Section Summary

At the beginning of each section in the student textbook are the Key Terms and section summary. Both can be used as a pre-reading strategy and a review tool. Before reading the text in the section, students should be able to define the Key Terms by scanning the text and using the Glossary. The Key Terms include terms from the curriculum outcomes and additional terms that are important for students to know and understand.

The section summary provides an overview of the key concepts being covered in the section. Students may not know all the concepts and terms described in the summary, but they can use this information to help guide them through their reading.

After reading the section, students can go back to the Key Terms and section summary to consolidate their understanding and identify areas that require clarification. At the end of the chapter or unit, students can use the Key Terms and section summary for review. BLM 2-2, Unit 2 Key Terms, and BLMs 2-7 and 2-8, Chapter 6 Key Terms, can be used to assist students.

Using the Activity

Find Out Activity 6-3A

Experimenting with a Simple Lens, p. 242

Purpose

- Students observe some properties of a test tube lens.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 day before	Gather materials.	For each student or pair: – glass test tube with stopper – water – paper or note card

Time Required

- 10 min

Safety Precautions

- Remind students to wipe up any spills immediately.

Science Background

The test tube lens models a convex lens with a high degree of curvature and a short focal length. These characteristics make it useful as a magnifying glass or a microscope.

Activity Notes

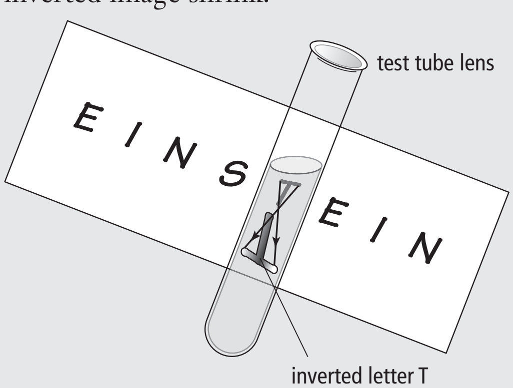
- As every student should have an opportunity to experiment with looking at type through the lens, have students work alone or in pairs.

Supporting Diverse Student Needs

- Students who have difficulty organizing their thoughts in writing can use a table to record their answers in What to Do points 4, 5, and 6.
- For enrichment, have students combine two or more lenses. Combining lenses creates a lens that is closer to the model for a modern microscope, but it is also trickier to make it work. Students may have better results using multiple tubes if they look at small print.

What Did You Find Out? Answers

1. With the test tube lens lying against the card, the letters are upright and magnified. As the test tube lens is lifted, the letters are still magnified, but become inverted. Continuing to raise the test tube lens higher makes the inverted image shrink.
2.



TEACHING THE SECTION, pp. 243–249

Using Reading

Pre-reading—Predict-Read-Verify

Break the section up into manageable chunks for students. Some suggested chunks are the following:

- Microscopes
- Telescopes
- Binoculars
- Cameras

Use the chunks as topic titles for discussion. Ask students to read the titles and subheadings and examine the diagrams to make a prediction about what each chunk will be about. The diagrams in this section convey important information, and examining them provides students with an opportunity to build their diagram-reading skills. Upon reading the student textbook, ask students to compare their predictions with what they learned.

Supporting Diverse Student Needs

- Reading diagrams is an important part of literacy. Model careful attention to the details of diagrams, labels, and captions by examining one or more of the diagrams in this section with students. Science Skill 8, Using Your Textbook, on page 492 of the textbook, includes information about using visuals in the textbook, as well as other helpful features.

During Reading—Note Taking

Encourage students to take notes as they read through each chunk. Have them include diagrams of each type of device showing how the optical components are arranged.

After Reading—Semantic Mapping

Have students review their notes and summarize them in chart format by comparing and contrasting a reflecting telescope with a refracting telescope, a refracting telescope with a pair of binoculars, a microscope with a camera, and a camera with a human eye. Students could work in groups to create these comparisons. Have one group begin each comparison, and then pass their paper to the next group, who would add any points they thought were relevant. This process would continue until all groups have a chance to add to every comparison chart. Since there are four comparisons, you would need four groups (or eight, if you worked with two separate rotations).

Students can summarize with they have learned using BLM 2-42, Making Things Bigger; BLM 2-43, How Does It Work?; and BLM 2-44, Comparing an Eye with a Camera.

Reading Check Answers, p. 249

1. The objective lens of a microscope collects light and focusses it into an enlarged image inside the body of the instrument. This image is then magnified again by the eyepiece lens, and directed into the eye of the microscope operator.
2. A reflecting telescope and a microscope both form an enlarged image inside the body of the instrument. This image is then magnified further using a convex lens.
3. The primary light-gathering device in a reflecting telescope is a concave mirror, whereas in a refracting telescope, it is a convex lens.
4. The Hubble Space Telescope is above Earth's atmosphere, which allows it to get a much clearer image of objects in space than Earth-bound telescopes.
5. Prisms in binoculars are used to shorten the two reflecting telescopes that make up binoculars. The prisms reflect the light back and forth, which increases the length of the light ray's path, simulating a longer telescope.
6. Telephoto lenses have a long focal length, while wide-angle lenses have a very short focal length.
7. Students' answers could include the following: The lens cap and the eyelid both provide protection. The diaphragm in the camera and the iris in the eye both control the amount of light that can enter. The image is inverted by the time it reaches the CCD detector in the camera or the retina in the eye.
8. Students' answers could include the following: The cornea is used in the eye to accomplish most of the focussing. There is no similar structure in a camera, which does all of its focussing with the lens. Some cameras have several lenses, while an eye has only one lens.

USING THE ACTIVITIES

- Activity 6-3A on page 242 of the student textbook introduces a moveable lens as a magnification tool. Detailed notes about this activity can be found in Introducing the Section.
- Activity 6-3B on page 244 of the student textbook explores the many different occupations that employ microscopes. It can be done at any time during this section.
- Detailed notes on doing Activity 6-3B follow.

Think About It Activity 6-3B

Microscopes on the Job, p. 244

Purpose

- Students discover how microscopes are used in a variety of occupations.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
1 week before	Arrange for access to computers and/or time at the library.	For whole class: – research materials

Time Required

- 30 min research time
- out-of-class time for additional research and to prepare the presentations
- Additional time for presentations and the What Did You Find Out? questions

Science Background

Students will need to sift through details in their research to find the essential elements that they think will accurately but briefly describe their chosen occupation. This process models scientific inquiry, which focusses on sorting out the main points, and recognizing that scientific knowledge is continually developing.

Activity Notes

- Have students work in small groups of three or four. You may need to teach students about positive group dynamics. Tasks such as decision making, consensus building, positive interactions, and delegating work among group members can be very difficult without some guidance.
- Some groups may choose to research a career not on the list in the student textbook. Have them consult with you about how they plan to gather information before they begin any research.
- Before conducting the presentations, prepare students by reading aloud the What Did You Find Out? questions. Doing so will help them focus on specifics during the presentations.

Supporting Diverse Student Needs

- Guide students to develop the interpersonal skills needed to work effectively in a group, for example, recognizing group members' different skills. In some cases, you may find it helpful to make some decisions for students to speed up progress.
- Allow groups to choose a method of presentation that will match the abilities, interests, or learning styles of students (e.g., oral presentation only with cue cards if necessary; research displayed on

a Bristol board; a skit showing an interview with a field expert, etc.).

What Did You Find Out? Answers

1.–4. Students' answers will vary depending on the research and the presentations.

USING THE FEATURE

National Geographic: Visualizing Lasers, p. 250

The process described in the article is called "stimulate emission" in which atoms in the ruby rod have been pumped full of energy by the light that surrounds the rod. However, the atoms can release only one wavelength of light. As a few of these emitted waves bounce back and forth millions of times between the two mirrors, other identical (same wavelength, same phase) waves of light are stimulated by these waves to be emitted from the atoms of the ruby rod. When the intensity gets great enough, some waves escape from the mirror system.

The discovery of lasers followed their prediction based on the theory of quantum mechanics first formulated by Einstein and others. As the theory of light led to the search for and discovery of radio, the theory of the atom led to the prediction of and later the discovery of lasers. After reading the feature, students could be asked to research where lasers are used today (e.g., laser eye surgery, fibre optics, laser pointers). If possible, bring in a laser pointer to demonstrate. Do not allow students to point it anywhere near anyone's eyes.

SECTION 6.3 ASSESSMENT, p. 251

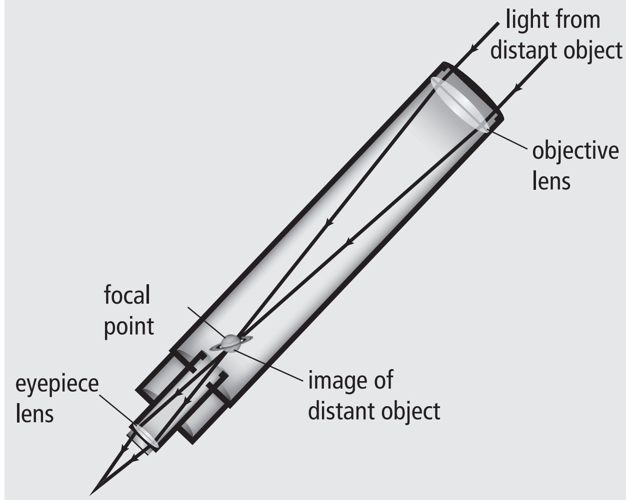
Check Your Understanding Answers

Checking Concepts

1. Students' answers could include the following:

CAMERA PART	FUNCTION
Lens cover	Protection
Lens	Collects light and magnifies image
Focussing ring	Moves lens in order to focus image
Diaphragm	Controls amount of light entering camera
Shutter	Controls whether light can reach the CCD
CCD	Detects light and converts it into an electrical signal

2. (a) and (b)

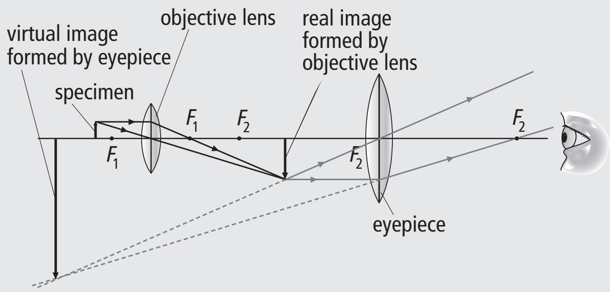


3. (a) The objective lens in a microscope produces a magnified image that is not seen directly.
   (b) Forming a magnified image inside the body of the microscope gives an opportunity to use a second lens to magnify the image even further.
4. A refracting telescope uses two convex lenses to produce a large image: an objective lens and an eyepiece lens. A reflecting telescope uses two mirrors (a concave mirror and a plane mirror) to create an image, which is then magnified by a convex lens.
5. A wide-angle lens has a short focal length, produces a small image of the object, and has a wide field of view. A telephoto lens has a longer focal length, produces an enlarged image that seems closer than it actually is, and has a small field of view.

Understanding Key Ideas

6. (a) Light from distant galaxies is extremely faint. To detect as much of this light as possible, large mirrors are used.
   (b) A large lens is inferior to a large mirror because it is extremely heavy, is costly and difficult to make, and even the best lenses change shape (if they are too large) and absorb some of the light, removing it from the formation of an image.
7. The final image of the object produced by a microscope is virtual. The compound microscope involves magnification of the object using two lenses. The objective lens forms a real image of the object inside the body of the

microscope, which then becomes the object for the eyepiece lens to magnify. The eyepiece lens produces a virtual image which can be seen by the eye when looking through this lens.



8. Modern research telescopes are large in order to be able to gather as much light as possible. As a result, objects such as distant galaxies appear much brighter, and their images can be magnified to a greater extent to reveal more detail.
9. Modern telescopes are very complex instruments. It is better for large groups of scientists and engineers to work together when designing and building modern telescopes so that experts are utilized in their area of expertise to create a technology in which every part works well.

Pause and Reflect Answer

Students' explanations may vary, but may include the following:

The photograph of Earth as seen from the Moon shows the entire Earth as a single, relatively small entity in the vast universe. Previous generations of humans may have considered the Earth to be essentially infinite in size. This belief meant that some people thought damage to Earth would have little lasting effect. For example, many people believed that throwing waste into the ocean would never be a problem because it would get diluted so much by the ocean water. This image shows that the Earth is finite, and every action that we carry out has a global impact whether we are aware of it or not (e.g., global warming, depletion of ozone layer).

The photograph of the bacteria reveals a whole world of life on a tiny scale that was unimagined only a few generations ago. This form of life is a major carrier of disease, and it explains how infections can be transmitted by failing to wash hands and cook food properly. Understanding how diseases are transmitted even though we cannot see them with the naked eye has saved countless lives.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

CHAPTER 6 ASSESSMENT, pp. 252–253

PREPARE YOUR OWN SUMMARY

Students' summaries should incorporate the following main ideas:

1. Ray Diagrams for Convex and Concave Lenses
   - Drawing three rays from the top of the object will allow you to predict the location of the top of the image.
   - For a convex lens, the first ray is drawn parallel to the principal axis, with the refracted ray passing through the focal point on the opposite side of the lens. The second ray passes through the near focal point, with the refracted ray running parallel to the principal axis on the opposite side of the lens. The third ray travels to the vertex and continues in a straight line through the lens. For an object between the focal point and the lens, these rays will need to be extended.
   - For a concave lens, the first ray is drawn parallel to the principal axis, with an extension of the refracted ray passing through the near focal point. The second ray is directed toward the focal point on the opposite side of the lens, with the refracted ray running parallel to the principal axis. The third ray travels through the vertex without refracting.
   - The image formed by a convex lens has different characteristics for size, position, orientation, and type, depending on the location of the object from the lens.
   - The image formed by a concave lens always has the following characteristics: smaller than the object, closer to the lens than the object, upright, and virtual.
2. How We See
   - In the cornea-lens-retina system, light rays pass through and are focussed by the cornea (transparent tissue on the outside of the eye in front of the pupil), then are refracted again at the flexible, transparent lens, to form an image at the retina (which contains cells that detect light and send electrical signals to the brain).
   - Rod cells detect shapes, movement, and shades of grey. They are very sensitive to light, and are the most abundant light-absorbing cells in the eye.

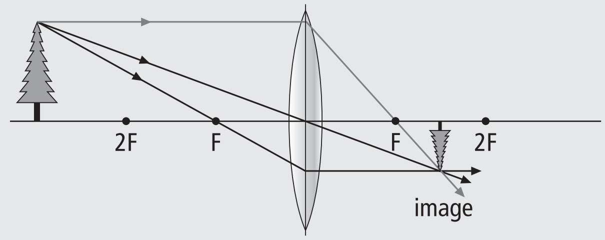
- Cone cells come in three varieties and detect different colours of light (blue, green, and red) with different efficiency. They are used for bright light vision, and are less abundant than rod cells, but they are concentrated at the centre of the retina, where sharp images are seen.

3. Correcting Focus Problems
   - Contact lenses or glasses can be used to correct many vision problems.
   - Near-sighted vision means close objects are seen clearly, but distant objects form an image in front of the retina instead of on the retina. A concave lens is used to correct this problem.
   - Far-sighted vision means distant objects are seen clearly, but nearby objects are unclear because the image tries to form behind the retina. A convex lens is used to correct this problem.
   - Astigmatism is a condition in which the cornea is shaped incorrectly and an image is focussed on more than one point on the retina, resulting in blurred vision. Corrective lenses can fix this problem, or laser surgery can be used to reshape the cornea.
4. Using Optical Systems to Magnify Close Objects
   - A microscope uses two convex lenses to magnify a nearby object.
   - In a microscope, the lenses are moved until the image comes into sharp focus.
5. Using Optical Systems to See Distant Objects
   - A refracting telescope uses two convex lenses to magnify a distant object. The eyepiece is moved to focus.
   - Telephoto lenses and binoculars employ refracting telescopes in their designs.
   - A reflecting telescope uses a large concave mirror to capture light and converge it toward a lens.
   - Astronomical telescopes tend to be reflecting telescopes (instead of refracting telescopes) because large mirrors weigh less and capture more light than a lens of the same diameter.

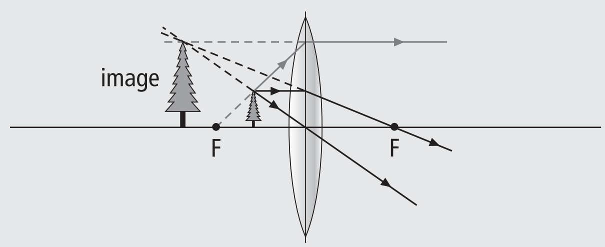
CHAPTER REVIEW ANSWERS

Checking Concepts

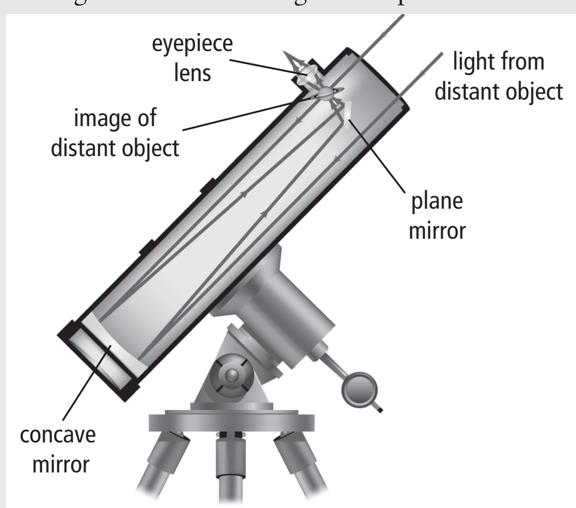
1. Convex lenses make parallel rays converge.
2. Concave lenses make parallel rays diverge.
3. (a) When the object is more than twice as far from the convex lens as the focal point, the characteristics of the image are the following: smaller than the object, closer to the lens than the object, inverted, and real.



   (b) When the object is between the convex lens and the focal point, the characteristics of the image are the following: larger than the object, farther from the lens than the object, upright, and virtual.



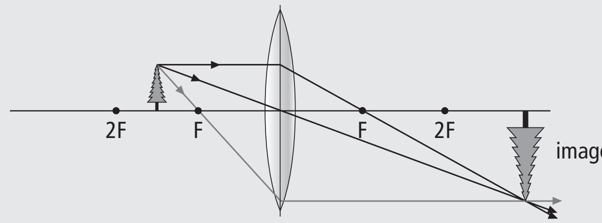
4. (a) A person who is near-sighted should use a concave lens, which helps diverge the parallel rays slightly so that the image forms on the retina, instead of in front of it.
   (b) A person who is far-sighted should use a convex lens, which will converge the light rays so they come into focus on the retina, instead of behind it.
5. Astigmatism is a condition caused by an irregularly-shaped cornea that makes it impossible to form a clear image. Sometimes several blurry images of the same object are produced.
6. Diagram of a reflecting telescope:



7. (a) In a microscope, the object being viewed is moved closer to or farther from the objective lens until it comes into focus.
   (b) This type of focussing does not work for a telescope because the distance of the object being observed cannot be moved farther from or closer to the telescope.
8. The shortening of the body of a pair of binoculars is accomplished by the use of prisms, which allow the light to travel a greater distance than the length of the binoculars by causing the incident light to reflect many times before reaching the observer.

Understanding Key Ideas

9. As people age, the lenses in the eyes become stiffer and the muscles cannot make the lenses change shape. Therefore, people cannot focus on nearby objects and need reading glasses to correct the problem.
10. Students' answers could include the following: When someone walks into a darkened room from full daylight, the pupil is too small to permit enough light to enter the eye. It takes a few minutes for the iris to respond by enlarging the size of the pupil. Also acceptable: Rod cells play a major role in low light vision and cone cells play a much lesser role. This adjustment takes a few minutes to occur.
11. Unlike mirrors, light can pass on either side of a lens. As a result, mirrors have only one focal point, while lenses have two focal points. The two focal points are located on each side of the lens and are always the same distance from the lens (for a lens with equal curvature on both sides).
12. When a person who is nearsighted looks at an object without wearing glasses or contact lenses, the image is blurry because it falls in front of the retina, and the light rays that actually strike the retina have begun to spread out again.
13. The type of lens that produces an image that is inverted, real, larger than the object, and farther from the lens than the object is a convex lens. The object is located between the focal point and twice the focal length.



14. (a) The objective lens or mirror in a telescope collects the incident light and forms a magnified image inside the body of the telescope.
    (b) The eyepiece lens magnifies the image formed by the first lens or mirror and directs the light rays into the eye of the observer.
15. A refracting telescope converges all incident light rays of an object to a single point. These rays then continue in a straight line from this point. As they leave the focal point, the image is inverted. The ray from the top of the object travels down, through the focal point, then continues down. The ray from the bottom of the object travels up, through the focal point, then continues up. Since the rays have crossed at the focal point, the image is inverted.
16. To focus on a distant object after focussing on a close object, less refraction is needed, because the light rays from a close object are diverging, whereas the light rays from a distant object are nearly parallel. Rays from a distant object will form an image closer to the lens than light rays from a nearby object. Therefore, the lens should be brought closer to the CCD.
17. (a) A very high magnification on a microscope may result in a darker image because the part of the object being observed is smaller, and fewer light rays reach the observer's eye.
    (b) Shining a brighter light on or through the object being observed can help to brighten the image.

Pause and Reflect Answer

Students' answers may vary. Sample answers: The availability of eyeglasses might cause a greater demand for books by people who would not otherwise be able to read them. Similarly, with the greater availability of books, the demand for eyeglasses would certainly increase. Even if eyeglasses were not available, books would be important. For example, even today, those who cannot read can still be read to.

UNIT 2 ASSESSMENT

PROJECT

Building an Optical Device, p. 256

Purpose

- Students design, build, and test a device that uses both mirrors and lenses.

Advance Preparation

WHEN TO BEGIN	WHAT TO DO	APPARATUS/MATERIALS
2–3 days before	Gather materials. Remind students to bring a ruler and pencil for the activity. You might ask students to bring any cardboard boxes or tubes they might need from home.	For each group: – variety of lenses (convex and concave) – plane mirrors (one or more) – cardboard – tape – scissors – glue – ruler – pencil

Time Required

- 15–30 minutes for brainstorming and/or research time
- 30–45 minutes for collecting materials, and assembling and testing the device
- Additional time for presentations

Safety Precautions

- Remind students to use care when handling scissors and mirrors that may have sharp edges.

Science Background

A catadioptric optical system is one that contains both lenses and mirrors. Examples of optical devices with at least one lens and one mirror include the following: telescopes, binoculars, and some cameras.

Activity Notes

- Have students work in small groups of three or four. You may need to teach students about positive group dynamics. Tasks such as decision making, consensus building, positive interactions, and delegating work among group members can be very difficult and time-consuming without some guidance.
- For groups having difficulty brainstorming ideas about what they will build, provide a list of possible devices, or allow them to conduct research on the Internet or at the library.

Supporting Diverse Student Needs

- This activity is a good hands-on activity for visual-spatial learners. It also helps develop skills in cooperative group work, problem-solving, and communication.
- Use a method of presentation that will match the abilities, interests, or learning styles of students (e.g., oral presentation, multimedia presentation, etc.).

Report Out Answers

1. Evaluate students' projects based on the construction of their device, demonstration, and explanation of how it works, and discussion of the problems encountered and solutions applied.
2. Have students hand in their original sketches along with a written evaluation of their device and how well it met the expectations.

Other Assessment Opportunities

- Consult the Unit front matter for a list of applicable Assessment BLMs.

INTEGRATED RESEARCH INVESTIGATION

Mirrors for Reflecting Telescopes, p. 257

Purpose

- Students research the application of mirrors for astronomical telescopes.

Activity Notes

- Have students work in pairs or small groups.
- To avoid listening to the same information over and over again as different groups present, you may divide the initial research so that each group reports on one of the questions listed in Find Out More on page 257.

Supporting Diverse Student Needs

- This activity is a good activity for students who like to research and organize information, as well as for visual-spatial learners who like to create posters, brochures, or multimedia presentations.
- Pair English language learners with more fluent speakers of English.

Other Assessment Opportunities

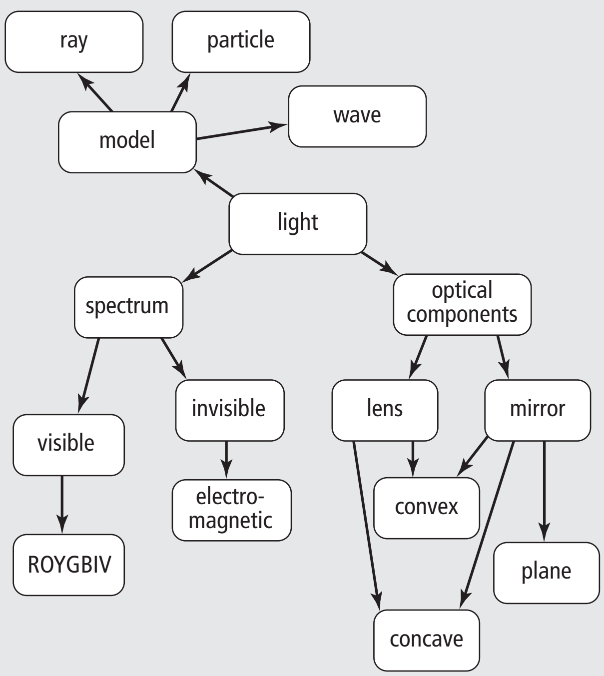
- Consult the Unit front matter for a list of applicable Assessment BLMs.

UNIT 2 REVIEW ANSWERS, pp. 258–261

In addition to the review in the textbook, students can prepare their own glossary for this unit using BLM 2-46, Make Your Own Glossary.

Visualizing Key Ideas

1. Students can use BLM 2-47, Light Concept Map to record their responses to question 1.

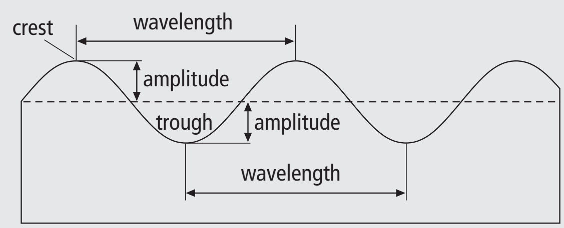


Using Key Terms

2. (a) False. The amplitude of a wave is the distance between the wave crest and the *equilibrium position*.
   (b) True
   (c) False. An *opaque* material prevents light from penetrating the object.
   (d) True
   (e) False. *Diffuse reflection* scatters light, preventing the formation of an image.
   (f) False. The angle of reflection is the angle between the reflected wave and the *normal* to the reflecting surface.
   (g) True
   (h) False. A *concave* mirror causes light rays to converge toward a focal point. Or, a convex mirror causes light rays to *diverge*.
   (i) False. Concave mirrors always *converge* light rays and can form images that are real.
   (j) False. When a ray passes from a less dense medium to a more dense medium, the ray bends *toward* the normal. Or, when a ray passes from a *more* dense medium to a *less* dense medium, the ray bends away from the normal.
   (k) False. Far-sighted vision results when light rays produce an image *behind* the retina. Or, *near-sighted* vision results when light rays produce an image before they reach the retina.
   (l) False. *Concave* lenses always form virtual images.
   (m) False. Microscopes and telescopes *both* have objective lens.
   (n) False. A refracting telescope is made of a combination of *lenses*. Or, a *reflecting* telescope is made of a combination of lenses and mirrors.

Checking Concepts

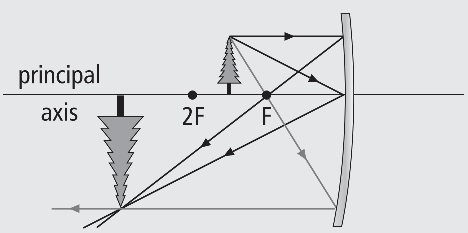
3. Students' answers could include the following: The invention of the microscope allowed scientists to study the microbial world. The development of the telescope allowed scientists to view the components of outer space in detail.
4.



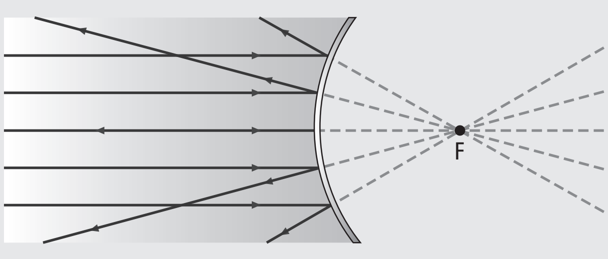
5. A prism causes the white light to refract and separate into its component colours: red, orange, yellow, green, blue, indigo, and violet.
6. Transparent materials allow light to pass right through without any change in direction. Translucent materials allow light through but scatter it in every direction.
7. Light is electromagnetic radiation and can travel through a vacuum but sound waves depend on particles and cannot.
8. Students' answers could include the following: Microwaves: microwave ovens, satellite communications (cell phone and television satellite dish), airport radar transmitters and receivers X rays: medical imaging (dental, CT scan), airport security scanning machines
9. The law of reflection states that the angle of reflection is equal to the angle of incidence.
10. In specular reflection, all incident rays hit the flat, smooth surface with the same angle of incidence, so they all reflect at the same angle

of reflection. In diffuse reflection, the angles of incidence for the rays are different because the surface is rough, so their corresponding angles of reflection are also different. Whether the surface is smooth or rough, each individual ray that strikes the surface obeys the law of reflection.

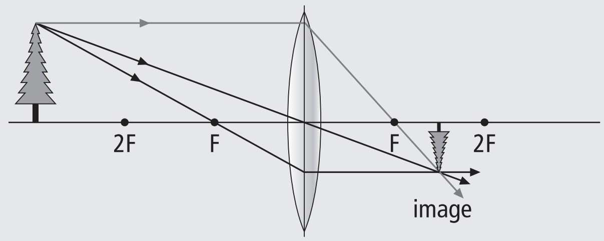
11. Waves travel more quickly through less dense materials. If a wave hits an interface between two materials of different densities, its speed will change. If it hits the interface at an angle, one side of the wave will slow down or speed up before the other, and the wave will change direction.
12. Images formed by plane mirrors are the same size as the object, the same distance from the mirror as the object, upright, and virtual.
13. The ray reflects off the mirror and travels parallel to the principal axis.
14. The characteristics of the image are the following: larger than the object, farther from the mirror than the object, inverted, and real.



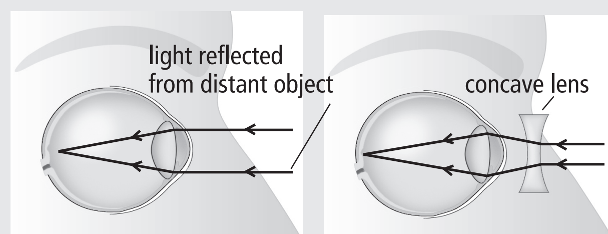
15. The focal point for a convex mirror is behind the mirror. To find its location, draw incident rays parallel to the principal axis, and extend the reflected rays behind the mirror until they meet.



16. A real image is an image formed when reflected rays meet. If you put a screen at that location, the image would appear on the screen. A virtual image is an image formed by the extension of the reflected rays. The light rays only appear to be coming from the image.
17. The refracted ray travels through the focal point on the opposite side of the convex lens.
18. The object must be located more than twice as far from the lens as the focal point.



19. As the object moves farther from a concave lens, its image becomes smaller and moves a little bit farther from the lens (but it is still closer to the lens than the object).
20. The lens is able to fine-tune our focus by changing its shape. When the eye focusses on a nearby object, the lens is very round. When the eye focusses on a distant object, the shape of the lens becomes flatter.
21. A concave lens is used to correct near-sightedness.

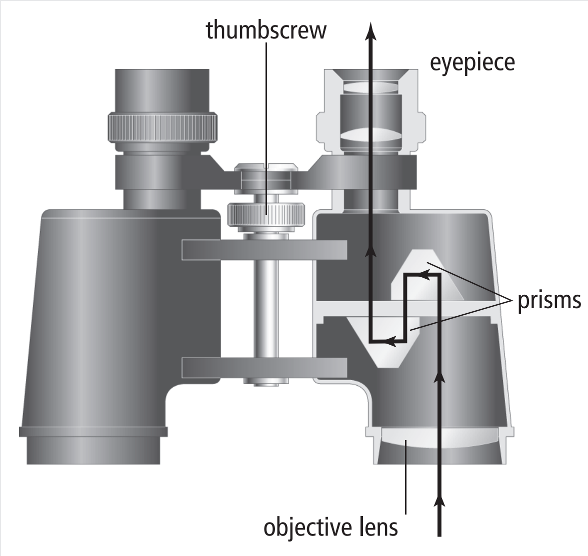


Near-sighted vision: image falls short of retina (eye has longer shape than normal eye)

Vision corrected with concave lens: lens allows image to fall on retina

22. Four common defects in human vision include the following:
    - Near-sightedness: the ability to see near objects clearly, but distant objects are fuzzy
    - Far-sightedness: the ability to see distant objects clearly, but close objects are fuzzy
    - Astigmatism: the inability to form a clear image or the tendency to form multiple blurry images
    - Colour blindness: the ability to distinguish some colours but not others

23.



24. Refracting telescopes and microscopes both use two lenses. In both devices, an objective lens collects the light and focusses it into an image, which is magnified by the eyepiece lens. However, the lens in a telescope has a longer focal length than in a microscope because the objects viewed are far from the lens.

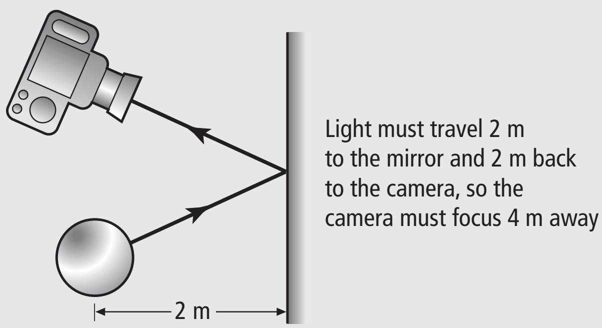
Understanding Key Ideas

25. Students' answers could include the following:
    - X rays are absorbed better by bone than by tissue, which allows an image of a skeleton to be formed. Very sensitive X-ray procedures can also differentiate between different types of tissues.
    - Radio waves are used in conjunction with strong magnets to make an image of different tissues and bones. The technique is called MRI or magnetic resonance imaging.
26. Students' answers may include these facts: Light and microwaves can both travel vast distances through a vacuum. Light and ultraviolet radiation are both produced by the Sun. Florescent materials can absorb ultraviolet radiation and emit light. Light and infrared radiation can both be reflected.
27. When light shines on a white page of black print, the black ink absorbs the incident light that hits it. The light that hits the white parts of the page produces diffuse reflection and the reflected rays go out in all different directions, reaching your eyes and allowing you to see white on the uneven surface of the paper.
28. The smoothness of the surface determines whether or not an image will be produced. An image is produced in a mirror because it is a smooth surface and produces specular reflection. Under a microscope, you will see that a piece of paper is not actually smooth, so it does not produce an image. Reflection is diffuse.
29. A concave mirror can produce a real image that can be captured on a screen. A convex mirror produces a virtual image that does not appear on a screen since light rays do not actually come from it.
30. Colour vision is detected by three kinds of cone cells, each of which detects a different part of the visible spectrum. When the three colours are received by the brain, the brain constructs a colour image from them. Black and white vision is detected by rod cells, which are very sensitive to dim light but do not distinguish any differences between different colours.
31. The objective lens is a convex lens used to form an enlarged image of the object. The eyepiece lens, which is another convex lens, then magnifies this image so that the final image can be hundreds of times larger than the actual object.
32. The green medium (A) is more dense than the blue medium (B) because the light is refracted away from the normal as it travels from A to B.
33. You can find the focal point of a convex lens by shining parallel beams of light through the lens. The rays will converge to a point and the distance from this point to the centre of the lens is called the focal length of the lens.
34. Mirrors have one focal point because light can pass only on one side. Lenses, on the other hand, have two sides through which light can travel, so they have two focal points.

Thinking Critically

35. Since no refraction occurs, the speed of light must be the same in both the plastic and the liquid.

36. To photograph the reflected image of an object that is 2 m in front of a mirror, the camera must focus 4 m away.

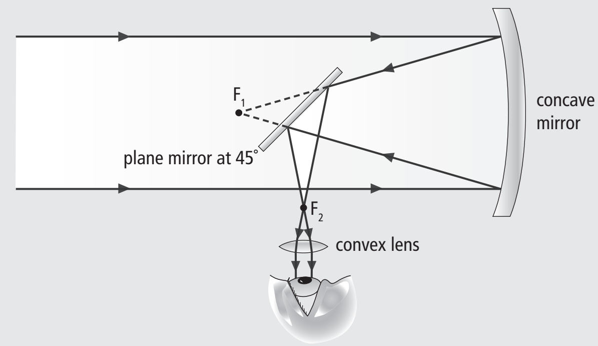


37. If you cover the left half of a convex lens, where the focal point is between the object and the lens, the right half of the image would disappear. If you cover the left half of a concave lens, the left half of the image would disappear.

Developing Skills

38. The distant object is located out of view at the leftmost side of the ray diagram. A ray from the top of the object travels parallel to the principal axis until it meets the centre of the lens, and the refracted ray passes through the focal point on the other side of the lens. The second ray coming from the distant object travels straight through the optical centre of the objective lens until it meets the first refracted ray. This location is where the real image of the distant object is formed. Now this image becomes the object for the eyepiece lens. One of the rays travels straight through the optical centre of the eyepiece, while the second ray passes through the near focal point to the eyepiece where the refracted ray runs parallel to the principal axis. The two refracted rays are extended back until they meet at the point where the virtual image is formed. Note that the diagram in the textbook is a schematic diagram only. Students should not be confused by the fact that the objective lens is drawn as symmetrical and the focal points are not equidistant from the lens.

39.



Pause and Reflect Answer

Bifocals are glasses that have corrective lenses containing two different optical powers; the top half of the glasses corrects for farsightedness and the bottom half corrects for nearsightedness. Bifocals are commonly prescribed to people who are near-sighted, but because of aging, they are beginning to experience problems focussing on near objects.