Topic 4.4
What is the law of reflection and how do mirrors form images?

Specific Expectations

- **E2.1** use appropriate terminology related to light and optics, including, but not limited to: *angle of incidence, angle of reflection, angle of refraction, centre of curvature, focal length, luminescence, magnification, principal axis, radius of curvature,* and *vertex*
- **E2.2** use an inquiry process to investigate the laws of reflection; use these laws to explain the characteristics of images formed by plane, converging (concave), and diverging (convex) mirrors, and draw ray diagrams to illustrate their observations
- **E3.3** explain the laws of reflection of light, and identify ways in which light reflects from various types of mirrors

Skills

- conduct inquiries to collect observations and data
- organize data using appropriate formats
- gather relevant information from research sources
- analyze and interpret data
- draw conclusions

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see pages TR-50 to TR-52 for a summary of the materials required in this topic.

Overview

In this topic, students will investigate laws of reflection and how mirrors form images. They will consider how and why smooth surfaces reflect light in predictable ways and analyze how convex and concave mirrors differ from plane mirrors. By the end of this topic, students will be able to use ray diagrams to represent how mirrors form images.

Common Misconceptions

- **Students think that regular reflection and diffuse reflection are completely separate phenomena.** Make specific reference to Figure 4.20 on page 307 to reaffirm that both types of reflection follow the same laws of reflection.
- **Students confuse concave mirrors and convex mirrors.** Both are spherical mirrors but the reflecting surface is on opposite sides. You may wish to use the mnemonic "You walk into caves, so a con**cave** mirror has the reflecting surface on the inside."

Background Knowledge

Light reflects in accordance with the three laws of reflection stated in the student textbook:

1. The angle of reflection is equal to the angle of incidence.
2. The reflected ray and the incident ray are on opposite sides of the normal.
3. The incident ray, the normal, and the reflected ray lie on the same plane.

Students generally have little difficulty understanding the first law, but the second and third laws need explaining. The first law is evident in sporting activities like hockey and tennis. The second law requires students to imagine a line standing at right angles to the reflecting surface; the incident ray and reflected ray occur on opposite sides of this imaginary line. The third law requires students to imagine that all of this occurs on a flat surface. Pool tables, hockey rinks, and shuffleboard courts are all examples of where these laws play out in everyday life.

Drawing ray diagrams to represent reflection requires care, but is not particularly difficult. Students must be willing to take as much time as is necessary to ensure lines are drawn with a ruler and a sharp pencil. Encourage students to make large drawings so that they are easy to see.

Literacy Strategies

Before Reading

- This topic lends itself to construction of a word wall. Allow pairs of students to select key terms or assign students key terms from this section. Have students look at the definitions, text, and diagrams in the topic to learn what their term means, and then present a definition to the class.
- ELL It is best to present concept maps to English language learners at the beginning of a topic, to give them the big picture: how mirrors form images, how smooth surfaces reflect light in predictable ways, how convex and concave mirrors differ from plane mirrors, ray diagrams, the laws of reflection, and so on. Some students may have little experience with activities and materials that provide background experience needed to understand the text. As the concept map is presented, show examples of each surface, using the pictures in the text. Add information and drawings to this map as the topic unfolds.
- Draw a simple ray diagram on the chalkboard, whiteboard, or on chart paper. Students should be able to place most key terms on the diagram. Leave this labelled diagram on display for students to use throughout the topic.

During Reading

- ELL English language learners are meeting new concepts as they struggle with making sense of syntax and vocabulary required to follow directions. Use Activity 4.9 to model the process of following directions and, as you read each direction aloud, explain terms like *focal length, upright, more than,* and *sharp image.* As you move through the activities, gradually release your role in the guided reading process.
- If you are asking student to make notes during reading, model explicitly the format you want your students to use. For example, date, title, point form or full sentences, main idea, supporting details, and so on.
- Encourage students to make connections with the text by writing in their notebook examples from everyday life connected to key terms, such as images, and examples of diffuse reflection and focal point. They can use a two-column format for taking notes as they read, writing notes from the text in one column and making connections in the other column.
- This is a long topic. Have students use the Learning Check questions at the end of each chunk to monitor their comprehension. They can compare answers with a classmate. If they do not agree on the best answers, pairs should look through the previous chunk of text and agree on a suitable answer. If necessary, model this for them.

After Reading

- Use some of the Learning Check questions to guide a class discussion on this challenging topic. Learning Check question 1 on page 309, Learning Check question 3 on page 316, and Learning Check question 3 on page 319 could initiate thoughtful discussion.
- Review the key concepts of this topic by completing a concept map about reflection with students. Alternatively, students could work in groups to develop concept maps, then share them with the class or display them.

Assessment FOR Learning

Tool	Evidence of Learning	Supporting Learners
Learning Check, page 307 Activity 4.8, page 311	Students describe the laws of reflection and apply them in ray diagrams.	• Demonstrate reflection with a basketball or volleyball bouncing off a spot on the floor. After each bounce, draw a diagram to illustrate it to show that the bounce always follows the laws of reflection.
Activity 4.8, page 311	Students draw ray diagrams to show that images in plane mirrors are almost identical to the object.	• Activity 4.11 provides further practice with observing reflection in a plane mirror. • Activity 4.12 provides practice with virtual images.
Activity 4.9, page 315 Learning Check page 315 Learning Check, page 316	Students draw and describe real and virtual images in concave mirrors accurately.	• Make explicit reference to the vertex, centre of curvature, and focal point when modelling the drawing of ray diagrams for spherical mirrors. Show that these are all on the principal axis. • Provide students with many opportunities to observe and identify images in a variety of concave mirrors that are real and virtual, and smaller and larger than the object. • Activity 4.14 and Investigation 4A provide additional experience with real images. • Students can use **BLM 4-9 Concave Mirror Template** to draw their ray diagrams.
Learning Check, page 319 Activity 4.10, page 321	Students draw and describe virtual images in convex mirrors accurately.	• Provide students with many opportunities to observe images in convex mirrors. Ask them to point to where each image appears to be. Ensure that they are pointing behind the mirror. • Activity 4.13 provides opportunities to compare images in plane, convex, and concave mirrors. • Students can use **BLM 4-10 Convex Mirror Template** to draw their ray diagrams.

Topic 4.4 (Student textbook pages 304-331)

Using the Topic Opener

- Ask students to look at the photograph on pages 304 and 305 and describe the reflections they see in the water. Lakes can be reflective when the water is calm and when it is wavy, but the type of reflection is different. When the surface is calm and flat reflection is regular, the images are almost identical to the objects being reflected. When the surface is wavy, diffuse reflection results in scattering of light, and the images are fragmented. Invite students to describe other reflections they have observed. Encourage discussion of reflections in different types of surfaces—smooth, rough, curved, wavy, and so on. Show pictures of these types of reflections.
- In all discussions, draw students' attention to the fact that the behaviour of light depends on the materials with which it interacts. This is a big idea related to all topics of this unit.
- Students will be required to draw ray diagrams throughout this topic. Ensure that students are prepared with sharp pencils, rulers, and erasers.

Starting Point Activity (Student textbook page 305)

Pedagogical Purpose

Students experience the laws of reflection first hand, and begin to predict paths of light based on their observations.

Planning	
Materials	Per group: ray box with slit 2 mirrors with stands **BLM G-51 Reflection Obstacle Course Template**
Time	20 min in class 10 min preparation
Safety	Caution students about safe use of electrical equipment.

Activity Notes and Troubleshooting

- Supply students with **BLM G-51 Reflection Obstacle Course Template**.
- The hands-on nature of this activity should engage students. Ensure that you have sufficient ray boxes and mirrors to enable all students to participate.
- Consider inviting a peer helper, preferably a senior physics student, to assist with management of the activity and crowd control.
- A flashlight and two locker mirrors can be used to demonstrate the reflection of light through 180°.
- ELL Some students new to Canada may not be familiar with the autumn colours we associate with our country. Invite students to explain briefly what they can expect to see in autumn.
- You could use modelling clay to support the mirrors in an upright position if you do not have stands.

Additional Support

- DI Pair students who have strong spatial or logical-mathematical skills with those require support to help activate their pattern-recognition abilities.
- Students with visual challenges will find this activity difficult. Have a classmate with excellent communication skills describe the process to them.

- DI Allow bodily-kinaesthetic learners to move around the room as they predict the path of light and direct the rays.
- ELL Pair English language learners with students who have strong English communication skills to help them understand what to do.
- Enrichment—If time permits, encourage students to develop their own creative obstacle courses, and challenge themselves or classmates to complete them. Several students could cooperate on a long obstacle course with several turns. Invite English language learners to create activities in their first language for other English language learners who speak the same language.

Starting Point Activity Answers

Students should use their understanding of angles and reflection to complete the obstacle courses.

Instructional Strategies for Topic 4.4

Student textbook pages 306–311

- Several key terms are introduced in this topic. The key terms on page 306 lay the foundation for all study of reflection. Use Figure 4.18 to ensure that students understand what is meant by each term. Students can use **BLM 4-11 Laws of Reflection** to create a summary of these key terms and the laws of reflection.
- Use a basketball or tennis ball to demonstrate the laws of reflection. Have students identify the angle of incidence, angle of reflection, incident ray, reflected ray, and normal for several different bounces on the floor and the wall.
- Examine the mirrors in Figure 4.21 on page 308 together. Invite students to suggest other types of mirrors they use or see in their daily lives. Classify these as plane mirrors and curved mirrors.
- All reflection follows the three laws described in this section. Remind students of this in later activities related to curved surfaces.

Student textbook pages 312–317

- Draw a large version of Figure 4.26 on page 312 or project it on an overhead. Use the diagram to help students understand the key terms related to concave mirrors.
- Model each step in Table 4.3 on page 314 for students, and then have them use the steps to draw a ray diagram of a reflection in a concave mirror. This modelling will be helpful when students are asked to draw their own ray diagrams in Activity 4.9 on page 315.
- After reading this section, students can use **BLM 4-12 Reflections in Concave Mirrors** to create a summary of the key terms on page 312 and of the characteristics of reflections in concave mirrors.
- Activity 4.13 on page 324 provides students with opportunities to experiment with reflections in a concave surface using a spoon.
- Activity 4.14 on page 325 provides students with opportunities to investigate real images.

Student textbook pages 318–321

- Consider having one student read the steps in Table 4.5 on page 320, while another student draws the diagram on the chalkboard or whiteboard, and the rest of the class draws the diagram in their notebooks. This strategy supports English language learners in their understanding. Have students who are drawing repeat the instructions as they draw to reinforce the concepts, vocabulary, and reading skills.

- Students can use **BLM 4-13 Reflections in Convex Mirrors** to create a summary of the characteristics of reflections in convex mirrors.

Learning Check Answers (Student textbook page 307)

1. The angle of reflection is the angle between the normal and the reflected ray.
2. Objects reflecting off a surface always do so in predictable ways. The angle at which light rays from the object strike the reflecting surface is the same as the angle at which the light rays leave the reflecting surface. The normal is an imaginary line drawn at right angles to the reflecting surface. The light ray from the object and its reflected ray are on opposite sides of this line. All of this occurs in a plane, or a flat surface.

Learning Check Answers (Student textbook page 309)

1. The image is located where the reflected rays, or the extension of the reflected rays, converge.
2. The object appears on the left of the diagram and the image is on the right. You know this because rays on the left or in front of the mirror are drawn with a continuous line and rays on the right or behind the mirror, known as virtual rays, are drawn with a broken or dashed line.

Activity 4.8 Drawing Ray Diagrams for Plane Mirrors

(Student textbook page 311)

Pedagogical Purpose

The purpose of this activity is to have students practise drawing ray diagrams to show the formation of images in a plane mirror.

Planning	
Materials	paper pencil ruler protractor **BLM 4-14 Activity 4.8** (optional)
Time	15 min in class

Skills Focus

- record information in ray diagrams

Activity Notes and Troubleshooting

- Students can draw their own diagram, as directed in the textbook, or they can use **BLM 4-14 Activity 4.8** to construct their ray diagram.
- Consider inviting a peer helper, preferably a senior physics student, to assist with management of this activity.

Additional Support

- DI Pair students who have strong spatial or logical-mathematical skills with those who require support to activate their pattern-recognition abilities.
- Students with visual challenges may find this activity difficult. Have a classmate with excellent communication skills describe the process to them.
- ELL You may wish to pair English language learners with classmates who have good English communication skills to help with understanding and answering the questions.
- Students could work in small groups, with each student following a step on Table 4.2, then comparing with other group members to ensure they are on track. Groups could discuss their answers to the What Did You Find Out? questions, then contribute to a class discussion.

Activity 4.8 Answers

What To Do

Diagrams should be similar to the diagram for step 5 in Table 4.2 on page 310.

What Did You Find Out?

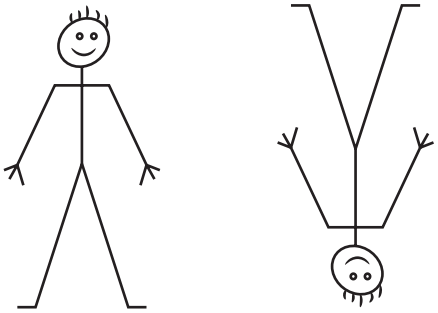
1. The size of the tree and its image were identical.
2. The image and object distances were identical.
3. Images in plane mirrors are identical in size and are located the same distance from the mirror as the object.

Learning Check Answers (Student textbook page 311)

1. Since the incident ray is on the normal, the reflected ray will also be on the normal. They will be on the same line, so the reflected ray is easy to draw.
2. Two points are required to mark the top and bottom of the images.

Learning Check Answers (Student textbook page 313)

1. The principal axis of a concave mirror is drawn by extending a line from the centre of the mirror through the centre of curvature.
2. The focal point is located exactly half way between the centre of curvature and the mirror.
3.



Activity 4.9 Drawing Ray Diagrams for the Region Beyond *C*

(Student textbook page 315)

Pedagogical Purpose

The purpose of this activity is to have students practise drawing ray diagrams to show the formation of images in a concave mirror for objects located beyond the centre of curvature.

Planning	
Materials	paper ruler pencil **BLM 4-15 Activity 4.9** (optional)
Time	15 min in class

Skills Focus

- record ray diagrams
- gather quantitative data
- draw and justify conclusions

Activity Notes and Troubleshooting

- Students can create their ray diagrams on **BLM 4-15 Activity 4.9**.
- Consider inviting a peer helper, preferably a senior physics student, to assist with management of this activity.
- Have students stop after step 2 and compare their diagram with a classmate's diagram before they measure and analyze it.

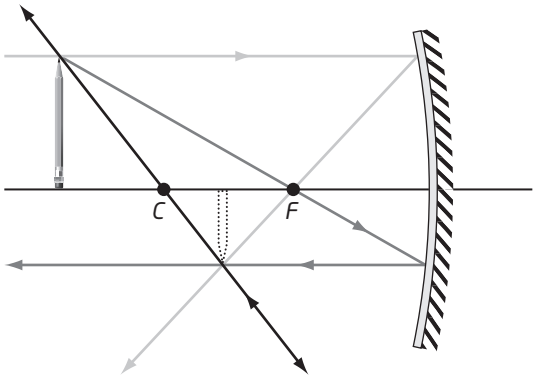
Additional Support

- DI Pair students who have strong spatial or logical-mathematical skills with those require support to activate their pattern-recognition abilities.
- Students with visual challenges may find this activity difficult. Have a classmate with excellent communication skills describe the process to them.
- DI Allow bodily-kinaesthetic learners to move around the room, perhaps to simulate the rays of light.
- ELL You may wish to pair English language learners with classmates who have strong English communication skills.

Activity 4.9 Answers

What To Do

2.



3. a), b) The image height should be smaller than that of the object.

c), d) The image location should be closer to the mirror (between *C* and *F*) than the object.

4. The image is located in front of the mirror.

5. The image is real because it could be captured on a screen held between *C* and *F*.

6. a) The location is in front of mirror, between *C* and *F*.

b) The orientation is inverted.

c) The size of the image is smaller than the size of the object.

d) The type is real.

What Did You Find Out?

1. The image of an object located beyond *C* is smaller than the image for an object located between *F* and *C*. It is also located closer to the mirror. Both images are real and inverted.

Learning Check Answers (Student textbook page 315)

1. Venn diagrams should include the following points.

   Between *F* and *C*: upright, larger

   Beyond *C*: inverted, smaller

   Both: real image

2. Place the object between *F* and *C*.
3. The reflected ray travels through the focal point.
4. The image characteristics for objects placed exactly at *C* are real, inverted, and the same size and distance from the mirror.

Learning Check Answers (Student textbook page 316)

1. Images in concave mirrors can be real or inverted depending on where the object is relative to the mirror.
2. If no ray actually goes through *F*, then draw the ray from the object to the mirror so that the extension of it would go through *F*. Then the reflected ray will travel parallel to the principal axis.
3. No image will form if an object is placed directly at *F*, because all rays will be reflected parallel to the principal axis.

Learning Check Answers (Student textbook page 319)

1. A spoon has a concave side (the bowl side) and a convex side (the outer side).
2. The focal point of a convex mirror is located on the opposite side of the reflecting surface, while the focal point of a concave mirror is located on the same side as the reflecting surface.
3. It is not possible to place an object between *F* and *C* of a convex mirror and still get an image, because the object would be on the opposite side of the reflecting surface.

Activity 4.10 Trends in Images in Convex Mirrors

(Student textbook page 321)

Pedagogical Purpose

In this activity, students practise drawing ray diagrams to show the formation of images in a convex mirror for objects located at different distances from the reflecting surface.

Planning	
Materials	paper ruler pencil **BLM 4-10 Convex Mirror Template** (optional)
Time	25 min in class

Skills Focus

- record information accurately in ray diagrams
- gather and interpret quantitative data

Activity Notes and Troubleshooting

- Consider inviting a peer helper, preferably a senior physics student, to assist with management of this activity.
- Students can copy the diagrams in the textbook or record their answers on **BLM 4-10 Convex Mirror Template**.
- You may wish to have students compare their results in step 2 with a classmate before taking measurements and interpreting them.

Additional Support

- DI Pair students who have strong spatial or logical-mathematical skills with those whose skills need developing to activate their pattern-recognition abilities.
- Students with visual challenges may find this activity difficult. Have a classmate with strong communication skills describe the process to them.
- DI Allow bodily-kinesthetic learners to move around the room to simulate the rays of light.
- ELL You may wish to pair English language learners with classmates who have strong English communication skills.

Activity 4.10 Answers

What To Do

Diagrams should be similar to the diagram for step 4 in Table 4.5 on page 320.

What Did You Find Out?

1. The object closer to the reflecting surface had a larger image.
2. The object farther from the mirror had an image closer to the focal point, and closer to the mirror.
3. Images in convex mirrors are always smaller than the object. Images in convex mirrors decrease in size, and get closer to the focal point, as the object moves farther from the mirror.

Learning Check Answers (Student textbook page 321)

1. The back of the spoon can act as a convex mirror.
2. The focal point for a convex mirror is located on the non-reflecting side, half way between the mirror and the centre of curvature. The focal point can be found by drawing incident rays parallel to the principal axis, then extending the reflected rays behind the mirror. They will meet at the focal point.
3. An image cannot form beyond the focal point for a convex mirror. The farther from the mirror the object is, the closer to the focal point the image gets. An object very, very far away, like the Sun, would have light rays parallel to the principal axis. The extension of those reflected rays would converge at the focal point, not past it.

Activity 4.11 How Light Reflects (Student textbook page 322)

Pedagogical Purpose

In this activity, students investigate the laws of reflection and practise drawing ray diagrams to show the reflection of light for plane mirrors.

Planning		
Materials	plane (flat) mirror ray box with single slit ruler	protractor white paper pencil
Time	25 min in class 10 min preparation	
Safety	Caution students about safe use of electrical equipment.	

Skills Focus

- work cooperatively
- use equipment and materials safely and effectively
- record information in ray diagrams

Activity Notes and Troubleshooting

- This activity provides a useful hands-on introduction to reflection in a plane mirror. While it can reinforce the material on pages 308 to 311, it could also be a useful introduction to reflections in plane mirrors.
- Consider inviting a peer helper, preferably a senior physics student, to assist with management of this activity.
- Students should work in groups of two to four for this activity. Ensure that all students has a chance to record the position of rays and to measure angles.

Additional Support

- DI Spatial, logical-mathematical, and bodily-kinesthetic learning will all play an important role in this activity. As much as possible, ensure that each group includes students with strength in these areas.
- Students with visual challenges may find this activity difficult. Have a classmate with excellent communication skills describe the process to them.
- ELL Pair English language learners with classmates who have strong English communication skills.
- To help students who require support following written instructions, demonstrate step 1 to step 7 for the class before they begin.

Activity 4.11 Answers

What To Do

Diagrams should be similar to the diagram for step 5 in Table 4.2 on page 310.

What Did You Find Out?

1. The two angles should be the same.
2. The two angles should be the same.
3. Rays going toward a plane mirror are reflected back at exactly the same angle as the angle at which they strike the mirror.
4. Place the ray box at 90° to the reflecting surface to make the reflected ray go straight back along the ray going from the ray box toward the mirror.

Activity 4.12 Like, Where's the Likeness (Student textbook page 323)

Pedagogical Purpose

This activity provides students with opportunities to investigate the laws of reflection and experience reflection of an image in a plane mirror.

Planning	
Materials	2 candles in holders (the candles must be identical) matches, or another method of lighting the candles plane mirror with stand sheet of paper ruler
Time	25 min in class 10 min preparation
Safety	Caution students about the safe use of candles.

Skills Focus

- work cooperatively
- use equipment and materials safely and accurately

Activity Notes and Troubleshooting

- Consider inviting a peer helper, preferably a senior physics student, to assist with management of this activity, including watching for safety issues once candles are lit.
- Instead of candles, students could use small battery powered lamps that produce a light bright enough to observe in this activity.
- While this activity can reinforce what students learn on pages 308 to 311, it can also serve as an introduction to virtual images. If students begin with the hands-on experience of trying to locate a virtual image in this activity, they should be better able to understand the meaning of the ray diagrams they draw on pages 310 and 311.
- Before tracing the bottom of the image candle in step 6, every group member should have an opportunity to check and confirm the candle's placement.

Additional Support

- DI Pair students who have strong spatial or logical-mathematical skills with those require support to activate their pattern-recognition abilities.
- Students with visual challenges may find this activity difficult. Have a classmate with excellent communication skills describe the process to them.
- DI Allow bodily-kinaesthetic learners to move around the room, perhaps to view the candles from the image side.
- ELL You may wish to pair English language learners with classmates who have strong English communication skills.

Activity 4.12 Answers

What Did You Find Out?

1. The distances from the line to the candles should be the same.
2. The orientation of both candles was right side up.
3. The apparent size of the candle and its reflection should be the same.

Activity 4.13 See Yourself in a Spoon (Student textbook page 324)

Pedagogical Purpose

This activity provides students with an opportunity to investigate the laws of reflection and compare the reflection of light in curved and plane mirrors.

Planning	
Materials	plane (flat) mirror large kitchen spoon with very shiny, reflective surfaces
Time	10 min in class 5 min preparation

Skills Focus

- gather and interpret qualitative data

Activity Notes and Troubleshooting

- This activity would be best done by each student individually. Students can meet in groups to discuss their results.
- This activity could be done to consolidate the key concepts of this topic, or to introduce reflections in concave and convex mirrors. Students could complete the activity before reading pages 312 to 321, and again after reading. They should work with a classmate and use what they have learned to explain why they see the images they do.

Additional Support

- ELL You may wish to pair English language learners with classmates who have strong English communication skills to help them understand the procedure and questions.

Activity 4.13 Answers

What Did You Find Out?

1. The image was larger in the curved mirror.
2. The image appears to be farther behind the mirror with the curved mirror.
3. The image in the curved mirror changes in size and orientation depending on the distance from your eye and the side used. Also, the image in the curved mirror at any distance is somewhat distorted.
4. The image on the inside of the spoon can be upright or inverted and larger, whereas the image on the back of the spoon is always smaller and upright.

Activity 4.14 Reflecting an Image (Student textbook page 325)

Pedagogical Purpose

This activity provides students with an opportunity to investigate the laws of reflection and to capture a real image on a screen held at a distance from a concave mirror.

Planning	
Materials	concave mirror sheet of white paper for a screen bright light source, such as a window
Time	10 min in class
Safety	Caution students not to stare at bright lights.

Skills Focus

- work cooperatively
- use equipment and materials safely and effectively

Activity Notes and Troubleshooting

- This activity could be used as an introduction to real images, presented on page 312.
- Consider inviting a peer helper, preferably a senior physics student, to assist with management of this activity.
- Students should work in pairs for this activity.
- When one group manages to position the screen for an optimal image, invite other students to have a look. Knowing what they are looking for will help them to position their own screen.

Additional Support

- DI Pair students who have strong spatial or bodily-kinesthetic skills with those who require support.
- Students with visual challenges may find this activity difficult. Consider placing them in a group with two other students to support their observations.
- DI Allow bodily-kinaesthetic learners to move around the room, carrying the sheet of white paper to capture the image.
- ELL Support students' ability to follow the written instructions by demonstrating how to set up the equipment to capture an image.

Activity 4.14 Answers

What Did You Find Out?

1. For all objects located beyond *C*, the image will be smaller than the object.
2. The image on the screen will be upside down.

Investigation 4A Exploring Images with a Concave Mirror

(Student textbook pages 326–327)

Pedagogical Purpose

Students will consolidate what they have learned about the properties of reflection and the characteristics of images formed in a concave mirror by conducting an investigation, recording their results in a table, and drawing conclusions based on their observations.

Planning		
Materials	concave mirror lighted object such as a candle metre stick **BLM 4-16 Investigation 4A** (optional) **BLM 4-17 Investigation 4A Table** (optional)	white piece of cardboard to act as a screen two small pieces of masking tape
Time	55 min in class 15 min preparation	
Safety	Caution students about the safe use of candles.	

Background

Images formed by concave mirrors vary in size, location, and type depending on the location of an object with respect to the mirror. It is important to know the focal length of the mirrors to be used in the investigation. Ideally, the mirrors should have a focal length (f) of between 8 cm and 20 cm. Objects located between the mirror and F will appear as a virtual image that is larger than the object and located behind the mirror. An image will not form for objects located at F because the reflected rays will be parallel. For objects placed between F and C, a real inverted image will be formed that is larger than the object. If the object is placed exactly at C, the inverted image will be exactly the same height and distance from the mirror as the object. For objects located beyond C, the image formed is inverted and smaller than the object.

Skills Focus

- conduct an inquiry using standard procedures, equipment and materials
- collect observations and data
- analyze and interpret quantitative data
- communicate effectively for a purpose

Activity Notes and Troubleshooting

- This investigation can help students review and consolidate what they have learned about reflections in concave mirrors, and reflections in general. Students can work in groups. Students should record their own observations in a table and make their own conclusions.
- Consider inviting a peer helper, preferably a senior physics student, to assist with management of this activity.
- Caution students to be extremely careful with the placement of candles and the paper screen, and with moving around the candles once they are placed.
- You may wish to conduct this investigation as a demonstration with selected students acting as principal investigators. Students should record their own notes and make their own conclusions.
- Supply students with **BLM 4-16 Investigation 4A**.

Additional Support

- Students who require support creating a data table can record their observations on **BLM 4-17 Investigation 4A Table**.
- DI Pair students who have strong logical-mathematical skills with those who require support to activate their pattern-recognition abilities.
- Students with visual challenges may find this activity difficult. Have a classmate with strong communication skills describe the process to them.
- DI Allow bodily-kinesthetic learners to move around the room carefully, carrying the sheet of white paper to capture the image.
- ELL You may wish to pair English language learners with classmates with strong English communication skills to help them understand the instructions and questions.

Investigation 4A Answers

What To Do

Measurements may vary depending on the focal length of the mirror. For example:

Object Distance	Image Distance (cm)	Size of Image (cm)	Orientation of Image	Type of Image
greater than 2*f*	15	8	inverted	real
equal to 2*f*	20	12	inverted	real
between 2*f* and *f*	25	18	inverted	real
less than *f*	-8	18	upright	virtual

What Did You Find Out?

1. Focal lengths may vary.
2. As the object moves toward the mirror, the image moves farther away from the mirror.
3. At 2*f*, the object and the image are the same distance from the mirror.
4. As the object moves toward the mirror, the size of the object increases.
5. **a)** A real image forms when the object is located beyond *f*.
   b) A virtual image is observed when the object is located closer to the mirror than *f*.
6. For objects less than one focal length from the mirror, the image is upright, virtual, and larger than the object.

Using the Case Study Investigation (Student textbook page 328)

Literacy Support

Before Reading

- Ask students to predict the focus of the case study based on the title.
- Discuss the use of mirrors in a car, and what they allow the driver to do. Trucks often have additional mirrors to help drivers see behind the vehicle.
- Some English language learners may have had little experience with vehicles, other than as transportation to and from school. Discuss the picture and print key vocabulary: *motor vehicle, rear view, motorcycle, side mirror, helmet,* and *visor.* Read the caption and then have the students go to the paragraph for more detail.

During Reading

- Encourage students to discuss everyday experiences related to road safety and seeing what is around you.
- Ask students to watch for any words that they would not use every day. Take a moment to discuss the differences between words used in common everyday language and scientific terms.

After Reading

- Encourage students to reflect on places in their neighbourhood or school where mirrors could help prevent accidents.
- Have students answer question 1 on their own, then discuss their answer with a classmate and be prepared to contribute to a class discussion.

Activity Notes

- Encourage students to highlight terms or phrases they do not understand with sticky notes. After reading each section, clarify the meanings of these terms with students.
- Before students research their answers to question 2, talk about how they might find the information they need. Discuss good Internet search terms for this topic and other places students could look for information.
- Students can work in pairs and use a brainstorming process to develop suggestions in question 3.

Case Study Investigation Answers

Answers may vary.

1. For example, construction workers could use the glasses to be safer on a construction site.
2. Mirrors are used by dentists and doctors, by inspectors, by astronomers, and as security and signalling devices. Students may list uses related to these areas.
3. Students should identify a specific problem, a specific location, and a plan involving the use of a specific type of mirror to solve the problem.

Using Strange Tales (Student textbook page 330)

Literacy Support

Before Reading

- Review key terms, such as *metamaterials*, *refract*, and *prototype* with students.
- Ask students to predict the focus of the article based on the title.
- ELL Some English language learners may find the writing style in the introduction to this passage difficult. They may miss the play on words as well as the references to Wonder Woman and Harry Potter. Explain these references and the connection to metamaterials described in the passage.
- Ask students to watch for words that they would not use every day. Discuss the differences between words used in common everyday language and scientific terms.

During Reading

- Encourage students to discuss everyday experiences related to observation, such as blurred or blocked vision or camouflage.

After Reading

- Encourage students to reflect on experiences they may have had when they tried to find someone but could not see them. For example, when they were in a shopping mall surrounded by people or at an unfamiliar location.
- Have students discuss what they learned from the text with a partner and be prepared to contribute to a class discussion.

Instructional Strategies

- Many students will be familiar with television or movie characters who wear clothes that make them appear invisible. Activate this prior knowledge and connect students' experiences with the topic of light and its ability to bend.
- Pair students who have require reading support with strong readers to activate their literacy abilities.

Strange Tales Answers

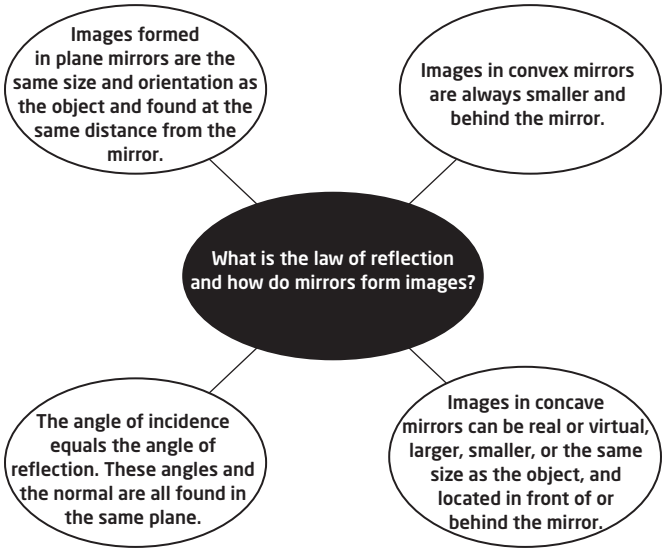
1. Some beneficial uses would be in television and live theatre where unusual effects could be managed by someone who is apparently invisible. Other advantages would be for people who hunt and fish. Negative uses would involve any threat to human life that could result from this means of cloaking. Students must explain their opinion and support it with valid points.
2. Answers will vary but should include concept of light and its ability to bend around the wearer of these types of garments.
3. If light is able to completely bend around you, then it is possible you would not cast a shadow. However, it is more likely that some type of shadow will result from this alteration in the path of light.

Topic 4.4 Review (Student textbook page 331)

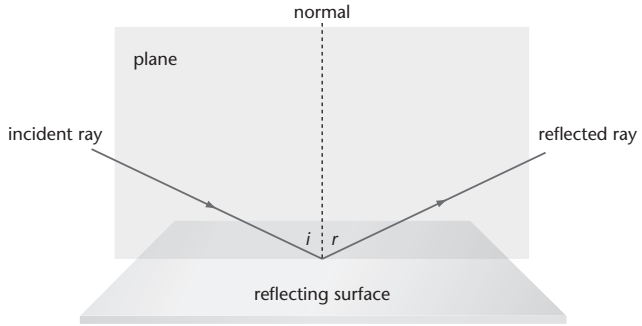
Please see also **BLM 4-18 Topic 4.4 Review (Alternative Format)**.

Answers

1. Answers may vary. For example:



2. The angle of the incident ray is equal to the angle of the reflected ray, the incident ray and reflected ray are on opposite sides of the normal, and both rays and the normal are on the same surface or plane.



3. To make a concave mirror, cut the ball in half and spray reflective paint on the inside of the ball. To make a convex mirror, spray reflective paint on the outside of the ball.

4. a) Use a concave mirror and place object between *F* and 2*F*.

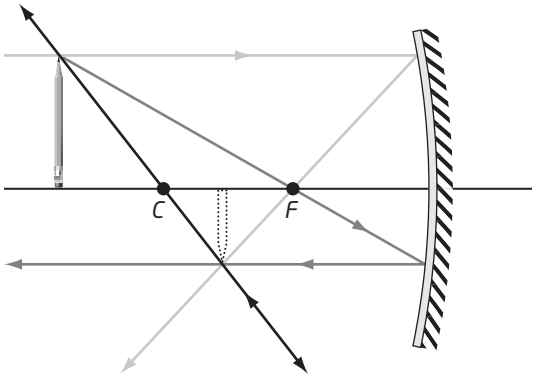
b) Use a convex mirror and place object any distance from mirror.

c) Use a plane mirror and place object any distance from mirror.

5. Draw one ray from the object to the top of the mirror parallel to the principal axis and its reflected ray through *F*. Draw the second ray through *F* to the mirror and its reflected ray parallel to the principal axis.

6. A concave mirror was used. The smallest focal length must be greater than 25 cm, because an object must be placed between *F* and the reflecting surface of a concave mirror to produce a virtual image.

7. The image is real, inverted, smaller than the object, and closer to the mirror.



8. In a convex mirror, the rays appear to converge behind the mirror. For this to occur, the extension of the reflected rays must occur closer to the principal axis than the object. Therefore, the image is smaller than the object.