TOPIC
3.3

How does light behave when it encounters different materials and surfaces?

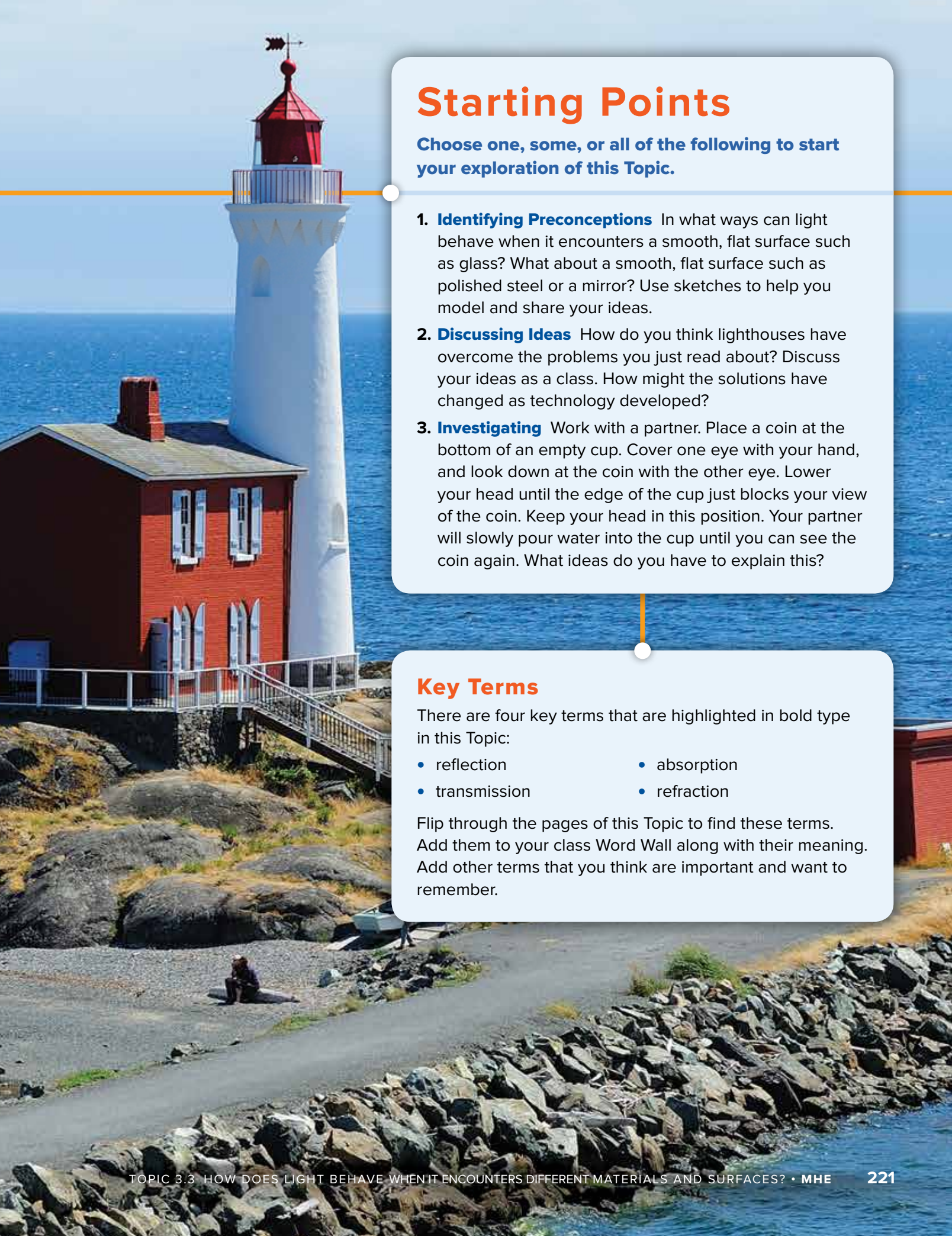
The Fisgard lighthouse has stood in the Esquimalt Harbour since 1860. It is the oldest lighthouse in British Columbia. Throughout history, lighthouses have had to address the dimming-with-distance problem for ships at sea to see their warning lights. Their lights also needed to be visible through dense fog. Lighthouses have overcome these problems in different ways over the centuries. However, the solutions have all taken advantage of how light behaves when it encounters different materials.

Key Concepts

- Light can be reflected, absorbed, transmitted, or refracted.
- Light behaves differently when it encounters transparent, translucent, or opaque materials.

Curricular Competencies

- Generate or introduce new or refined ideas while problem solving
- Make predictions about inquiry findings
- Express and reflect on a variety of experiences and perspectives of place
- Experience and interpret the local environment



Starting Points

Choose one, some, or all of the following to start your exploration of this Topic.

1. **Identifying Preconceptions** In what ways can light behave when it encounters a smooth, flat surface such as glass? What about a smooth, flat surface such as polished steel or a mirror? Use sketches to help you model and share your ideas.
2. **Discussing Ideas** How do you think lighthouses have overcome the problems you just read about? Discuss your ideas as a class. How might the solutions have changed as technology developed?
3. **Investigating** Work with a partner. Place a coin at the bottom of an empty cup. Cover one eye with your hand, and look down at the coin with the other eye. Lower your head until the edge of the cup just blocks your view of the coin. Keep your head in this position. Your partner will slowly pour water into the cup until you can see the coin again. What ideas do you have to explain this?

Key Terms

There are four key terms that are highlighted in bold type in this Topic:

- reflection
- transmission
- absorption
- refraction

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Light can be reflected, absorbed, transmitted, or refracted.

Light interacts with different materials and surfaces in different ways. Light may reflect, be absorbed, be transmitted, or refract.

reflection the process in which light "bounces off" the surface of an object and travels in another direction

Reflection: Light Bounces Off

When light strikes an object, it often just reflects from its surface. **Reflection** is the process in which light "bounces off" a surface and changes direction. There are two different types of reflection.

Reflection Off an Extremely Smooth Surface

Every time you look in a mirror, you see light reflect off an extremely smooth surface. This produces a clear image (a likeness) of you and your surroundings. This type of reflection also occurs on the surface of a very still body of water, like the one in Figure 3.17. You can also observe it on some polished surfaces, such as glass or metal. When such a surface reflects light, the pattern of reflected rays is very similar to the pattern of the incoming rays. This similarity is what lets you see an image when the light reaches your eyes (Figure 3.18).

Figure 3.17 In this photograph, Emerald Lake in Yoho National Park has an extremely smooth surface in which an image is visible.

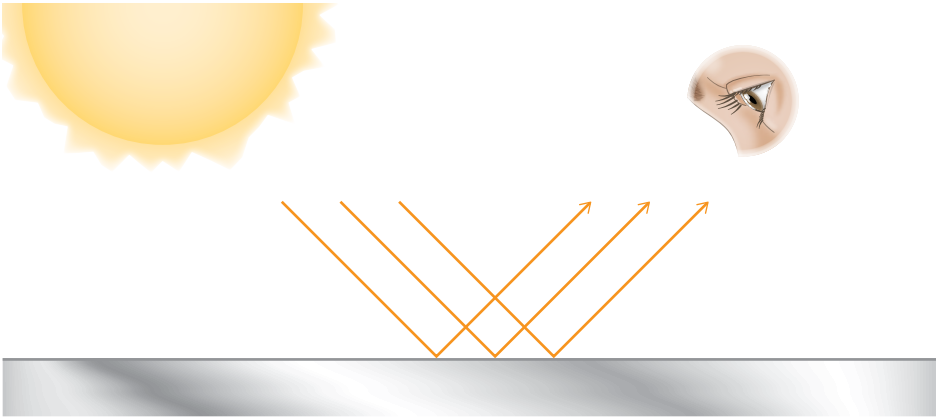


Figure 3.18 Light rays reflecting off a smooth, mirror-like surface have a pattern that is very similar to that of the incoming rays.

Reflection Off a Rough Surface

Light can also reflect off a rough surface, such as a piece of paper. This type of reflection does not produce an image. However, it does make objects visible. Figure 3.19A shows how this works. Notice how the reflected rays go in many different directions. The pattern of the reflected rays is no longer similar to the pattern of the incoming rays, so no image appears on the paper. However, some reflected rays do reach your eyes. These make the paper visible.

Why do the rays reflect in all directions? Paper might look smooth to the unaided eye, but Figure 3.19B shows otherwise. Under a microscope, the paper's surface looks rough and uneven. When light hits this surface, it scatters in many different directions.

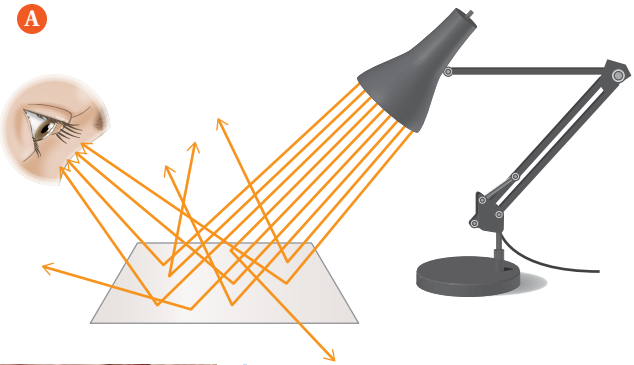


Figure 3.19 When light hits a rough surface, like paper, it reflects in many directions A. Some light enters your eyes, making the paper visible. B shows the paper's surface magnified.

Absorption: Light Energy Is Trapped

Absorption is the process in which light energy becomes trapped in an object as heat. Consider a piece of paper again, but this time one with a black letter on it, as in Figure 3.20A. Reflection off a rough surface lets you see the paper itself. However, the printed letter is made up of black ink that completely absorbs all incoming light. No rays reflect off the letter into your eyes, so it looks black.

What if the letter is a colour? You see colour when an object absorbs only part of the visible light spectrum. Some wavelengths of light are absorbed, and the rest are reflected. Figure 3.20B shows what happens when the letter on the paper is a colour, such as blue. The letter absorbs all colours except blue. The blue wavelengths are reflected from the letter into your eyes, so it looks blue.

absorption the process in which light energy is trapped in an object as heat

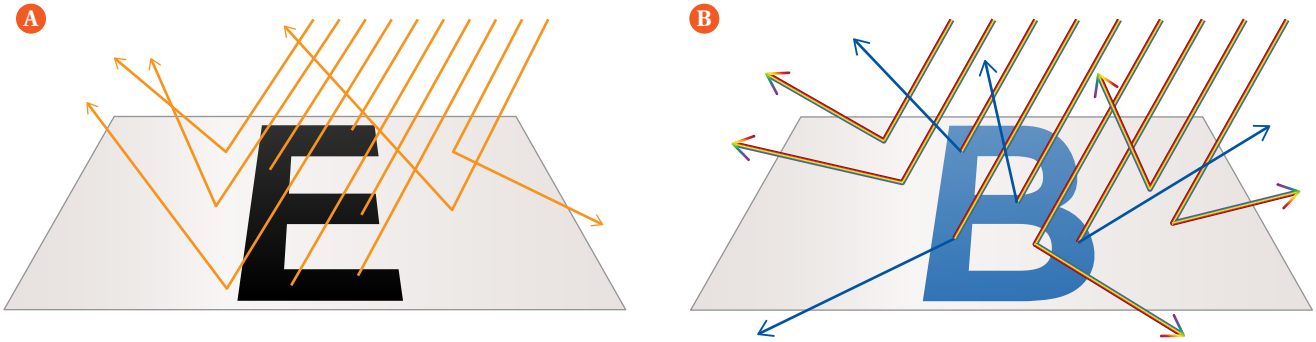


Figure 3.20 A Rays that hit the black letter are absorbed, so the letter looks black. B The blue letter absorbs all wavelengths of visible light except blue. Only the blue light reaches your eyes.

Transmission: Light Passes Through

transmission the process in which light passes through a medium and keeps travelling

Not all materials absorb or reflect all of the light that hits them. Some materials allow different amounts of light to pass through. For example, if you hold a white piece of paper to a light, some light comes through. When light passes through a material, that material is called a *medium*. **Transmission** is a process in which light passes through a medium and keeps travelling. Different materials transmit different amounts of light. For example, a clear glass window transmits more light than a sheet of paper.

Refraction: The Path of Light Bends

refraction the process in which light changes direction when it moves from one medium to another

Light does not change direction when it is travelling through the same medium. However, light does change direction when it moves from one medium to another. This process is called **refraction**. Figure 3.21 shows light refracting.

Use Figure 3.22 to see how refraction can trick your brain. The light reflected from the top part of the pencil travels in a straight line to your eyes through the medium of air. The light from the bottom part refracts. It changes direction slightly as it moves from water to glass to air. (Because light travels such a short distance through the glass, you don't really notice the change in direction caused by the glass.) Your brain believes light always travels in a straight line, so it has trouble determining the position of the bottom of the pencil. That's why the pencil looks broken at the water line.

Figure 3.21 This beam of red light allows you to see the path of light bend as it enters and leaves the water.

Figure 3.22 This pencil appears broken due to refraction. In reality, the bottom part of the pencil is not where your brain thinks it is.

Before you leave this page . . .

1. Use a flowchart to describe what can happen to light when it strikes an object.
2. The Moon is not a source of visible light. Why does it seem to glow brightly at night?

CONCEPT 2

Light behaves differently when it encounters transparent, translucent, or opaque materials.

Activity

How Is Light Transmitted?

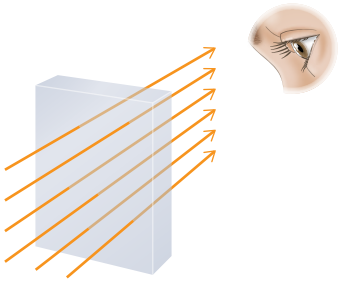
Inspect the materials your teacher gives you. Predict what happens to light as it strikes each one. Use a flashlight to test your predictions. Use your observations to refine your original predictions.

Figure 3.23 shows that a material can be transparent, translucent, or opaque based on how much light it lets pass through, how the light behaves, and if you can see through it.

Figure 3.23 Light interacts with different materials in different ways.

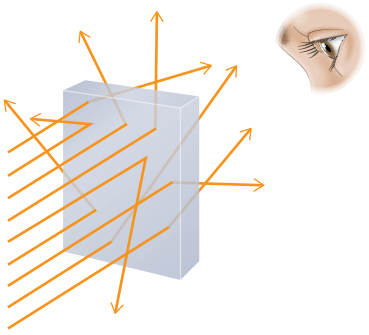
Transparent Materials Transmit Light

Transparent materials transmit almost all the light rays that strike them. Clear glass, plastic, water, and air are examples of transparent materials. Because transparent materials transmit most light, objects can be seen clearly through them.



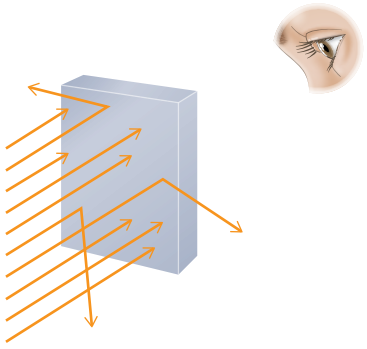
Translucent Materials Scatter Light

Translucent materials allow most light to pass through them. However, the light is scattered in many directions as it passes through. Frosted plastic and waxed paper are examples of translucent materials. Because translucent materials scatter light, objects seen through them are usually blurry.



Opaque Materials Reflect and Absorb Light

Opaque materials reflect and absorb light. These materials do not allow any light to pass through them. Wood, metal, and stone are examples of opaque materials. Because opaque materials do not allow light to pass through, objects cannot be seen through them.



Before you leave this page . . .

1. Choose a material from your daily life.
   a) Is the material transparent, translucent, or opaque? How could you confirm your decisions?
   b) Explain how the material's interaction with light is related to its function.
2. Some jellyfish are transparent. How might this affect their ability to survive?

AT ISSUE

How can natural optical phenomena be explained?

What's the Issue?

If you live near Golden, you may have caught a glimpse of a rainbow in the spray at Lower Bugaboo Falls. If you live near Kamloops or Osoyoos, you may have witnessed a mirage on the highway in the intense summer heat. The northern sky is a great place to observe a sundog—have you seen one? These optical phenomena occur as a result of light interacting with different materials of the atmosphere, such as water, dust, and ice crystals. As well as rainbows, mirages, and sundogs, other examples include the blue colour of daytime sky, the red colour of evening sunsets, auroras such as the Northern Lights, and cool-sounding crepuscular rays.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions of interest to explore.

1. What natural optical phenomena have you seen in B.C. and/or elsewhere? What sort of conditions were present when you saw them? For example, you might consider the time of day or year, the temperature, or the weather.
2. Choose at least one natural optical phenomenon. Investigate how it is understood scientifically as well as by other systems of knowing, such as the Traditional Ecological Knowledge of First Peoples. How do the different understandings compare—for example, what do we learn from one way that we don't learn from another? Is something lost (or gained) by using only one way to understand the optical phenomenon?

Check Your Understanding of **Topic 3.3**

QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating
AI Applying and Innovating C Communicating

Understanding Key Ideas

1. What materials do you know that reflect light? Give three examples. PA
2. What materials do you know that absorb light? Give three examples. PA
3. What materials do you know that transmit light? Give three examples. PA
4. Use the concepts of transmission, scattering, absorption, and reflection to explain what happens to visible light when it strikes each surface below. PA E AI C
   a) a transparent glass window
   b) a window covered by sheer curtains
   c) a window covered by blackout blinds
5. Explain why you can see your face reflected in a smooth glass mirror but not in a sheet of smooth white paper. PA C
6. The photo below was taken at Elk Lakes Provincial Park in the southeast part of B.C. Identify all the places you can see in this photo where light is being reflected, refracted, absorbed, and transmitted. PA E AI

7. What would the world look like if the following situations existed on Earth? Justify your responses. PA AI C
   a) objects no longer reflect light
   b) materials cannot transmit light
   c) all wavelengths of visible light are either reflected or absorbed (there is no in between)
   d) all objects transmit light

Connecting Ideas

8. Think about a typical school day. As you do your usual activities, you use many devices and objects. List three ways in which you use each of the following: PA AI
   a) something with an extremely smooth surface
   b) a transparent material
   c) an opaque object
   d) something that absorbs most light that reaches it

Making New Connections

9. Design an educational game based on the properties of transparent, translucent, and opaque materials. PA AI
10. Scientists have invented materials, called metamaterials, that cause light to behave in ways that it normally would not. It bends around the material and reconnects behind it, like water flowing around a rock or stump in a stream. Scientists hope one day to use metamaterials to make things appear invisible. Suggest a possible application for metamaterials that would benefit society. E AI

Exploring How Light Interacts with Different Materials

Skills and Strategies

- Questioning and Predicting
- Processing and Analyzing
- Evaluating
- Applying and Innovating
- Communicating

Safety

- The edges of the mirrors may be sharp. Be careful not to cut yourself.
- Be careful not to drop the mirrors.
- Never shine a light directly into someone's eyes.

What You Need

- a variety of objects and materials that reflect, absorb, transmit, scatter, or refract light
- construction materials, such as tape, glue, and scissors
- flashlight
- access to information resources

PART A: CREATE A LIGHT SCULPTURE—STRUCTURED INQUIRY

Question

How can you create a sculpture to demonstrate how light behaves when it strikes different materials and objects?

Procedure

1. Your teacher will provide objects and materials that reflect, absorb, transmit, scatter, or refract light. Use any of these to build a sculpture that will create various effects when light shines on it in a darkened room.
2. Copy the following table and give it an appropriate title.

Material or object	Predicted effects	Observed effects

3. Record each material or object that you plan to use.
4. For each, predict the effects you think it will create, as well as how you think light will behave. Add your predictions to your table.
5. Design and build your sculpture.
6. Your teacher will darken the room or take you to another room where this is possible. Shine light on your sculpture. Observe and record the effects, as well as how light interacts with each material or object. Add your observations to your table.

Analyze and Communicate

1. Explain the understandings you used to make your predictions. How well did they match your observations?

PART B: APPLY YOUR UNDERSTANDING—GUIDED INQUIRY

Blackfoot architect Douglas Cardinal, reflecting on the designs he created for Canada's Museum of Civilization in Ottawa, said: "Instead of viewing the museum as a sculptural problem…I prefer to take a walk in nature, observe how nature has solved its problems, and let it be an inspiration to me in solving mine." He believes, "Our buildings must be a part of nature, must flow out of the land; the landscape must weave in and out of them so that, even in the harshness of winter, we are not deprived of our closeness with nature."

Architects like Douglas Cardinal, as well as other artists and designers, make use of materials that interact with light in different ways. They use the materials to create desired effects in their creative works.

Question

How can you apply your understanding of light and materials to achieve intended effects?

Procedure

1. Choose an artist, architect, or designer who interests you. Do research to find out how the materials that he or she works with interact with light and what techniques can be used to create different effects of light, shadow, and colour.
2. Reflect on your findings. Decide how you can apply your understanding in designing a creation of your own. This could be a building plan, a painting, a garden, a ceremonial space, a stage set for a performance, or anything else you choose.

Evaluate and Communicate

1. In the research stage of your inquiry, what did you discover that you did not know before? How else did your research introduce you to new ideas or help you refine ideas you already had?
2. How did your research help you develop your plan for your creation?
3. How can you use input from others to help you assess and refine your creation?