12 Optical devices help us see farther and more clearly than we can with unaided eyes.

Astronomers use a copper vapour laser and a reflecting telescope to stabilize the twinkling images of stars.

Skills You Will Use

In this chapter, you will:

- identify and locate print and electronic sources that are relevant to research questions
- gather data from laboratory and other sources, and organize and record the data using appropriate formats, including tables, flowcharts, graphs, and/or diagrams
- select, organize, and record relevant information on research topics from various sources, including electronic, print, and/or human sources

Concepts You Will Learn

In this chapter, you will:

- analyze technological devices that use properties of light
- explain how optical devices have enhanced society
- analyze technological devices and procedures related to human perception of light
- evaluate the effectiveness of technological devices and procedures related to human perception of light

Why It Is Important

Our knowledge of human vision helps us to correct and extend our ability to see, which helps us to understand and appreciate our universe. Optical devices such as microscopes and telescopes use mirrors and lenses to help us see objects that are very small or very far away.

Before Writing

Thinking Literacy

Write for Your Reader

Good writers put themselves in the place of their readers, and so they make their writing easy to understand and interesting to read. Skim section 12.1, and choose two subtopics. Read at least one paragraph under each subtopic. What made the information easy to understand and interesting?

Key Terms

• astigmatism • compound microscope • cornea • far-sighted • laser • near-sighted • photonics • photons • reflecting telescope • refracting telescope

12.1 Human Perception of Light

Here is a summary of what you will learn in this section:

- Focussing of light in your eye is accomplished by the cornea, the lens, and the fluids contained in your eye.
- Light is detected by the retina, which contains rod cells, used for low light vision, and cone cells, used for bright light colour vision.
- Far- and near-sightedness and astigmatism are conditions in which the eye is not able to converge light rays correctly in order to form a clear image on the retina.
- Many types of vision problems can be corrected.

Figure 12.1 Human vision can detect many aspects of an object including shape, colour, and movement.

Perceiving Light

How is your vision? If you have good vision, you can be reading this page, look away to see a distant object, and then continue reading, always in perfect focus. You can recognize shapes in Figure 12.1 and in the classroom. You can quickly detect when something moves, even at the edge of your visual field. If the light is bright enough, you can make out a vast range of colours. If the room becomes dark, you can no longer see colour, but you can still detect shapes among the shadows.

Perception of light is an amazing ability, but it is not an ability that everyone shares equally. Many people benefit at some point in their lives from technologies or procedures that improve perception of light. For example, on a bright day, polarized sunglasses can both reduce glare and block harmful ultraviolet rays. Anti-glare night vision glasses can help drivers filter out light rays that can be a problem at night when trying to see past the headlights of oncoming cars. Even the reflection of light bouncing off of the white page of a textbook can make it very difficult for some people to read the black letters of the text. In this case, eyeglasses with a blue or yellow tint can be helpful. Visual perception is a very complex process that involves both eyesight and using your brain to make sense of the images received by your eyes.

Vision testing is normally done by a trained professional called an **optometrist.** In some situations, the optometrist will refer you to a physician who specializes in eye care, called an **ophthalmologist** (Figure 12.2).

Eye exams normally take about half an hour. Your eye care provider will have you identify letters or shapes on an eye chart and may place different lenses in front of your eyes to find out whether this can help you see more clearly. Other tests include checking for double vision, depth perception problems, and colour vision deficiencies. There is even a test to measure the pressure inside your eye. By catching problems early, it is often possible to correct problems or to prevent problems from getting worse.

Figure 12.2 An ophthalmologist uses a device called an ophthalmoscope to determine whether contact lenses are a good choice for correcting a patient's vision.

D27 *Quick Lab*

What Do You See?

Purpose

To use different aspects of vision to make sense of images

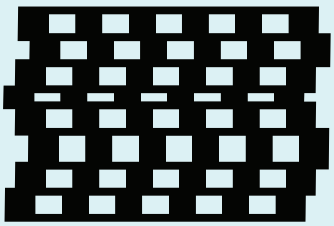


Figure 12.3 Step 1

Figure 12.4 Step 2

Figure 12.5 Step 3

Procedure

1. Are the horizontal lines in Figure 12.3 straight or curved? Make a prediction. Then use a ruler to check the result.
2. There are two different images in Figure 12.4. What do you see? Ask classmates what they see.
3. The Canadian flag in Figure 12.5 is coloured black and blue-green. Stare at the flag for about 20 s, and then immediately look at a white page. What do you see? You may need to try this several times.

Questions

4. For Figure 12.3, suggest whether the ability to detect edges and straightness occurs in the eye, the brain, or both.
5. For Figure 12.4, suggest whether the ability to give meaning to an image occurs in the eye, the brain, or both.
6. For Figure 12.5, suggest whether the ability to adapt to changes in colours occurs in the eye, the brain, or both.

Human Vision

In order to evaluate optical technologies related to the human perception of light, it can be helpful to understand how your own eyes work to focus light and detect images (Figure 12.6).

The outer surface of your eye where light enters is made of a transparent layer of tissue called the **cornea**. Light can pass right through the cornea because even though it is made of living cells, it is completely clear. Your cornea is made of strong tissue that is tough enough to protect your eye and hold it together, while remaining extremely sensitive to touch. The cornea is about as thick as a credit card and is sensitive enough to send you a strong pain signal if anything touches it. If it suffers from a small scratch, the cornea can heal itself. The light rays that arrive at your eye are refracted by the cornea. This helps direct the light correctly into your eye. Without the refractive properties of your cornea, you would not be able to focus.

WORDS MATTER

"Pupil" is derived from the Latin word *pupa*, meaning little doll, indicating the tiny reflections of people visible in pupils. The word "iris," the name of the structure that determines eye colour, is derived from the Greek word for rainbow.

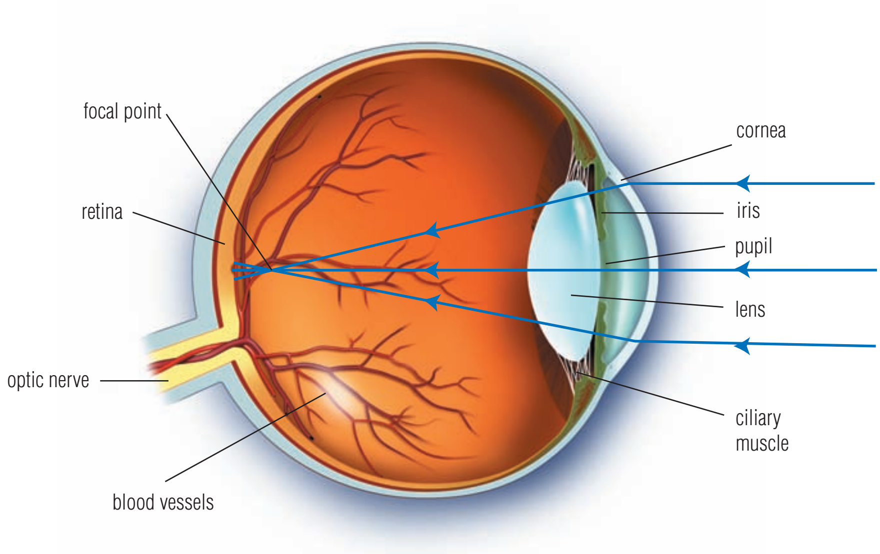


Figure 12.6 A cross-section of the human eye

After passing through the cornea, the light rays reach the pupil. The **pupil** is the dark circle that you see when you look at someone's eye. It is actually just a hole that allows light to pass into the eye. The pupil is black for exactly the same reason the entrance to a cave appears dark — light rays enter the cave but do not leave. The pupil is created by a circular band of muscle called the **iris**. When people refer to their eye colour, they are referring to the colour of the iris. The iris controls the size of the pupil, and so it controls the amount of light that enters the eye. In dim light, the iris opens and the pupil dilates (becomes wider) to let in more light. In bright light, the iris closes and the pupil contracts (becomes smaller) so that less light enters (Figure 12.7). Changes in pupil size happen automatically; you do not have to think about it.

(a)

(b)

Figure 12.7 (a) Dilated pupil and (b) contracted pupil

Focussing the Light

Good eyesight requires precise focussing of light rays onto the retina. The **retina** is the inner lining at the back of the eye that acts as a projection screen for the light rays entering your eye (Figure 12.8). Most of the focussing of light in your eye is done by the cornea. However, the entire eye is a focussing system that involves the cornea, the lens, and even the spaces in front of and behind the lens that are filled with a watery fluid.

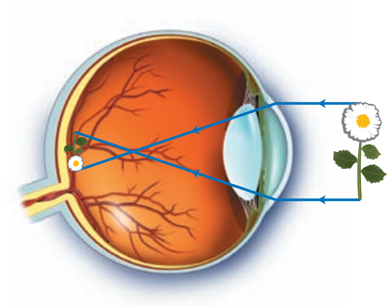


Figure 12.8 The image formed on the retina is inverted, but your brain interprets the image as being right side up.

Changing the Shape of the Lens

You may recall that a convex lens collects light and directs it to a focal point. Your eye includes a convex lens. Your lens allows you to change your focus so that you can see an object clearly regardless of whether it is right in front you or all the way out at the horizon. The lens is able to adjust its focal length because, unlike the cornea, it is attached to a tiny circle of muscles that can change its shape (Figure 12.9). When the muscles supporting your lens contract, the circle they form shrinks. This releases tension on your lens, allowing it to expand on its own into a more spherical or thicker shape. Your lens can now strongly refract light, which helps you focus on very near objects. Try focussing on this page when it is very close. You may be able to feel the muscles in your eye working.

When the circular muscle is relaxed, the circle they form expands, pulling your lens flatter and thinner. This is excellent for seeing distant objects. You may have noticed that if you allow your eyes to relax, nearby objects, such as this textbook, go out of focus, but distant objects are clear.

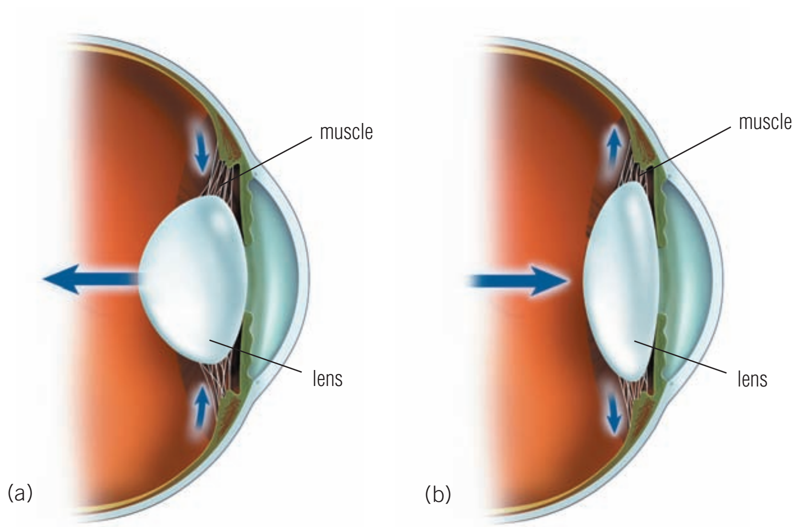


Figure 12.9 The muscles change the shape of the lens so you can focus on objects at various distances. (a) Position of muscles and shape of lens when focussing on nearby objects and (b) distant objects

Detecting Light

Suggested Activity •
D28 Inquiry Activity on page 478

Getting light into the eye and focussing it on the retina are only part of the task of seeing an image. In order for you to see, light rays must be absorbed by **photoreceptors**, which are cells in the retina that are sensitive to light. Photoreceptors include rod cells and cone cells (Figure 12.10). **Rod cells** help us detect shapes and movement in low light situations. Our brain does not recognize differences in colour from signals gathered by rod cells. Instead, we detect only shades of grey. Most of us are so used to our low light vision abilities that we do not even notice that we are not seeing in colour. **Cone cells** are photoreceptor cells used to detect colour. In humans, cone cells come in three types, each of which detects a different primary colour of red, green, or blue particularly well.

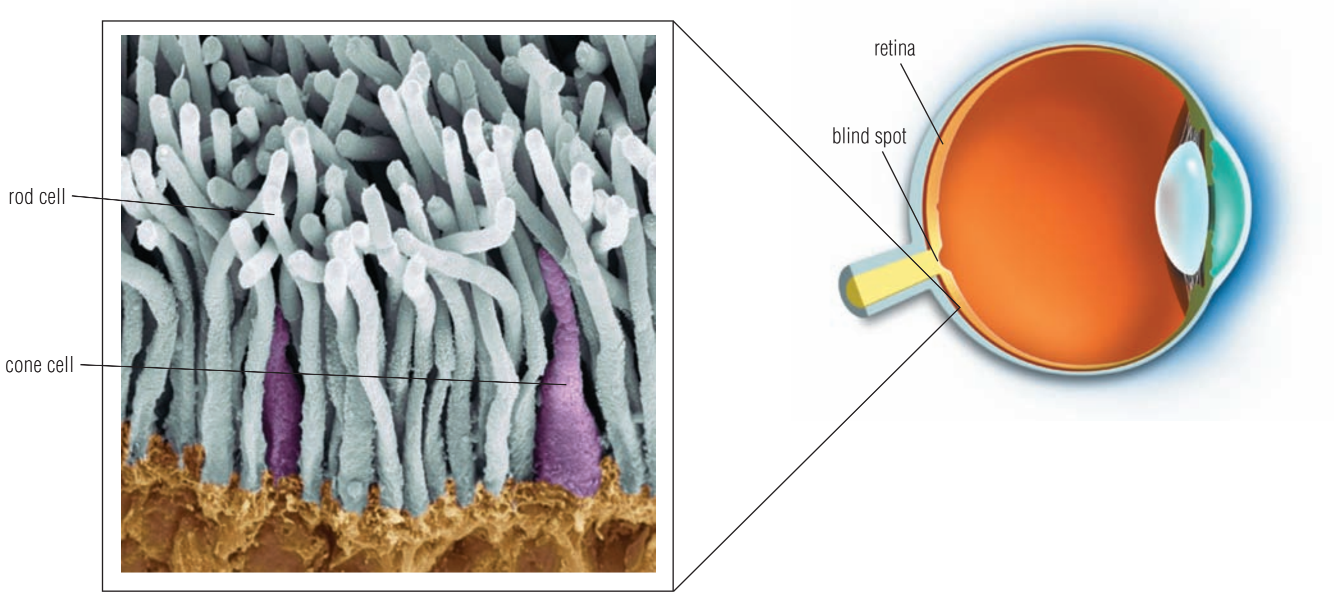


Figure 12.10 This is a false-colour electron micrograph image showing rod and cone photoreceptor cells in the retina at a magnification of 1800× at 10 cm. Cones are found in the central region of the retina. The more numerous rods are located outside the central region of the retina.

There is one place on the retina of every healthy eye called the blind spot, which has no photoreceptors and which cannot detect light. The **blind spot** is the place where the optic nerve attaches to the retina. The **optic nerve** connects your eye to your brain. You do not notice your blind spot because your brain "fills in" that spot with whatever colours are nearby in what you are looking at. You can use Figure 12.11 to help you detect your blind spot.

Figure 12.11 To find the blind spot in your right eye, close your left eye, and stare at the plus sign. Slowly move the book toward you and away from you. When the black spot disappears, you have found your blind spot.

Learning Checkpoint

1. What is the function of the cornea?
2. What structures control the amount of light that enters the eye?
3. What is the function of the retina?
4. What are two types of photoreceptors?
5. Where is the blind spot located?

Correcting Vision Problems Using Lenses

The most important and widespread technological device related to human perception of light is the lens, whether it is a lens made of tempered glass or hardened plastic used in eyeglasses or a tiny plastic contact lens that floats on your cornea. Almost any focussing problem can be improved by placing a lens in front of your eyes.

Many people have trouble focussing clearly at some point during their life. Focussing problems sometimes occur in young children and teenagers, as their eyes grow along with the rest of their body. With aging, many adults become less able to see nearby objects clearly as the lenses in their eyes gradually harden and become less able to change shape. Most eye problems fall into one or more categories: far-sightedness, near-sightedness, and astigmatism.

Far-Sightedness

People who are **far-sighted** can see distant objects clearly, but they cannot see nearby objects clearly. The light rays from nearby objects diverge more strongly than rays from distant objects, which enter the eye nearly parallel. In far-sightedness, the eye cannot make the lens thick enough to refract diverging light rays from nearby objects correctly on the retina. Instead, the image falls into focus behind the eye, resulting in a blurry image on the retina. Adding a converging lens in front of the eye helps the light rays form the image correctly on the retina as shown in Figure 12.12.

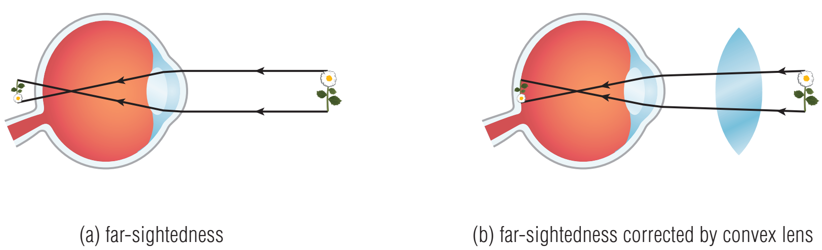
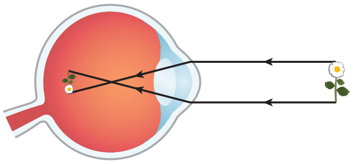


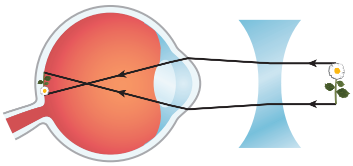
Figure 12.12 (a) Far-sightedness and (b) far-sightedness corrected by a converging lens

Near-Sightedness

People who are **near-sighted** can see nearby objects clearly but cannot see distant objects clearly. In near-sightedness, the nearly parallel rays that arrive at the eye from distant objects are refracted so much that the image forms in front of the retina instead of on it. This happens because the eye cannot make the lens thin enough, resulting in a blurry image. To correct near-sightedness, a diverging lens is placed in front of the eye, causing light rays from distant objects to diverge as they approach the eye. The eye then causes the light rays to converge properly, just as with light rays coming from nearby objects, and the light rays fall correctly onto the retina in focus (Figure 12.13).



(a) near-sightedness



(b) near-sightedness corrected by concave lens

Figure 12.13 (a) Near-sightedness and (b) near-sightedness corrected by a diverging lens

Astigmatism

A common condition is called **astigmatism**, in which the eye is unable to form a clear image because of an irregular shape of the cornea or lens. For example, the cornea may be shaped more like a football than the typical baseball shape. This irregular shape causes an image to be formed on more than one place on the retina, which results in blurry vision (Figure 12.14).

There are two general types of astigmatism. In one type, the eye refracts light better along the vertical axis. In this type, a person has difficulty seeing horizontal lines clearly, such as in the letters E or F. In the second type of astigmatism, the eye refracts light better along the horizontal axis and the person has difficulty focussing on vertical lines like I and J. Common symptoms of astigmatism include headaches and fatigue.

Almost all eyes have some irregularities in the shape of the cornea or lens. However, astigmatism needs to be corrected only if it interferes with normal vision. Like both far-sightedness and near-sightedness, astigmatism can be corrected with eyeglasses, contact lenses, or laser surgery (Figure 12.15).

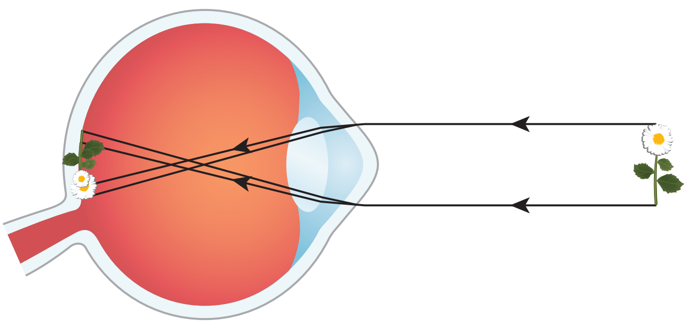


Figure 12.14 Astigmatism is a vision problem that results from a cornea that has an irregular shape.

Figure 12.15 Contact lenses sit directly on the cornea and can be used to correct far- and near-sightedness as well as astigmatism.

Reshaping the Cornea

Laser eye surgery is a general term for several different kinds of procedures that involve correcting vision by reshaping the cornea using energy from a laser (Figure 12.16). The procedures can be used to correct far- and near-sightedness as well as astigmatism. Millions of people worldwide have had successful laser surgery, eliminating their need for corrective lenses. However, as with any surgical procedure, it is not without risk. In some cases, laser surgery leads to poor night vision or problems caused by dry eyes.

Figure 12.16 Laser surgery, also called refractive eye surgery, reshapes the cornea in order to allow the eye to focus correctly.

Laser surgery is not suitable for everyone who might want it. This is due to differences in eyes from one person to another. The first task of every laser surgeon is to assess whether the procedure is appropriate for an individual patient and, if so, to give the patient enough information to make an informed decision. Some people delay having laser surgery because the procedure is only several decades old, and the long-term effects of laser surgery are not yet known.

During Writing

Thinking Literacy

Writing to Analyze

Scientists begin their writing with an important idea, question, or problem. They ask "What is important and why?" Then, they provide background information to help them draw a conclusion. When you analyze issues, start with a question, and then find the information you need to understand the answer.

Suggested STSE Activity

D29 Decision-Making Analysis Case Study on page 480

Learning Checkpoint

1. Where does the image form in persons who are far-sighted?
2. What type of lens is used to correct far-sightedness?
3. Where does the image form in persons who are near-sighted?
4. What type of lens is used to correct near-sightedness?
5. What causes astigmatism?

Optical Technologies for Persons with Blindness

You may have heard the term "blindness" applied to any type of vision impairment that prevents someone from being able to do important activities such as reading, driving a car, or seeing their friends clearly. Total blindness means that the person does not perceive any light at all. The term "legally blind" is often used to describe people with very low vision who, even with corrective lenses, would need to stand about 6 m from an object to see it as clearly as a normally sighted person could from about 60 m away. The term "legally blind" is also applied to people whose visual field is less than 20° instead of the 180° seen by those with normal vision.

Almost all people who are legally blind are able to detect some degree of light and form an image of some kind (Figure 12.17). For example, a legally blind person might be able to see using peripheral vision but not be able to form an image in the centre of the visual field. In another case, a legally blind person might see only a tiny spot at the centre of the visual field and not have any peripheral vision.

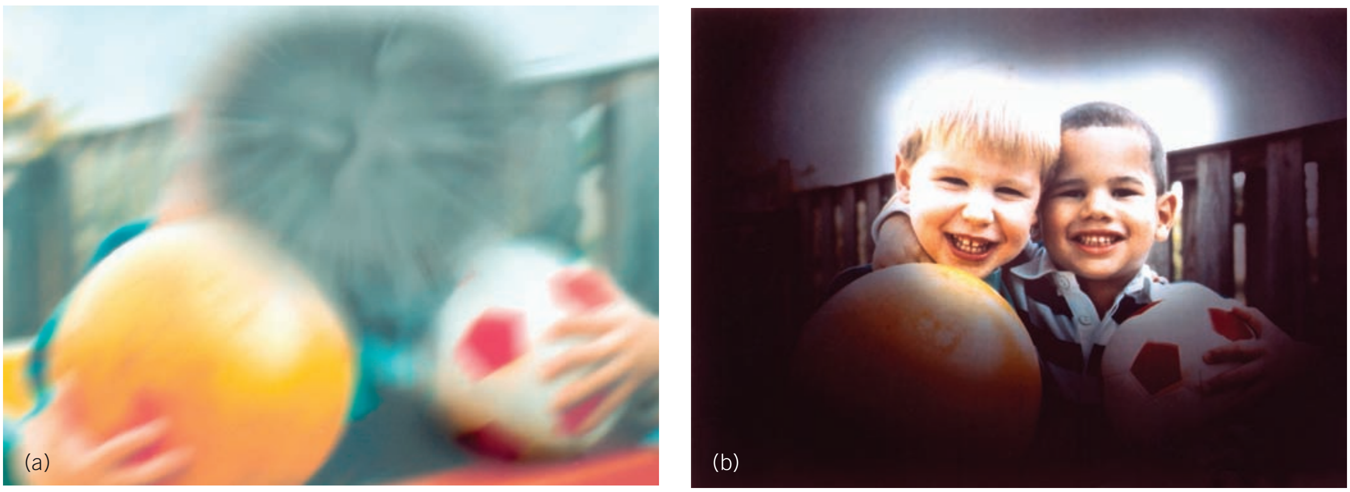


Figure 12.17 (a) Loss of the centre of vision field and (b) loss of peripheral vision

Many people who have very low vision can have most of their sight restored by wearing glasses or contact lenses or through surgery. For example, laser surgery can be used to help re-attach a retina that has become detached from the back of the eye. Laser surgery can also be used to remove cataracts, which are cloudy areas of the lens. Some treatments, such as retinal implants, are still very experimental. A retinal implant is an experimental procedure in which an electronic device is surgically implanted into the retina in order to replace natural photoreceptors that no longer function. The device can digitally detect light and transform it into electrical signals that can stimulate functioning parts of the retina to send signals to the brain.

Colour and Vision

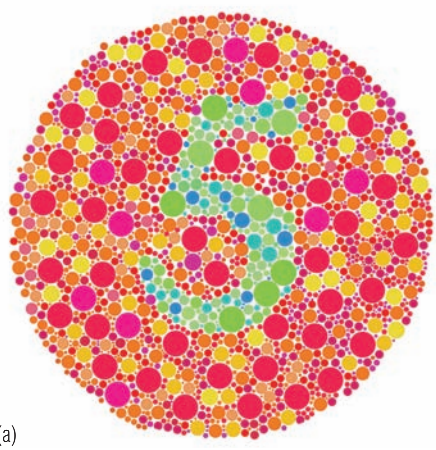
True **colour blindness**, which is the ability to only see shades of grey, is very rare, occurring in about 1 person in 40 000. Colour-blind persons are able to see which traffic light in a stop light is on, but they cannot tell whether it is red or green. They must be careful to remember the position of the red and green relative to each other. Colour blindness is not always a disadvantage. In some cases, it allows a person to be able to more easily recognize an object set in a highly complicated colour background.

Colour vision deficiency is a more common condition, occurring in about 1 percent of females and 8 percent of males. **Colour vision deficiency** is the ability to distinguish some colours but not others (Figure 12.18). In one form of colour vision deficiency, often referred to as red-green colour deficiency, red and green appear to be the same colour. This is due to a lack of cone photoreceptors that detect red. Many people are not even aware that they have a colour vision deficiency until they are in their teens or later.

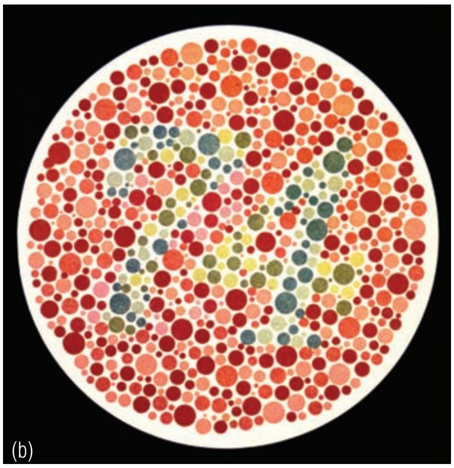
Some persons with a perceptual condition called dyslexia find it difficult to read text if it is written on a white background. In many cases, eyeglasses with coloured filters make reading much easier as they make the page appear to be coloured.

Take It Further

One of the roles of vision is to judge how far away objects are. Distance cues such as the size of familiar objects are called monocular cues, because only one eye is needed. The use of two eyes allows the brain to construct a 3D image and is called binocular vision. Find out more about depth perception using monocular and binocular vision. Begin your research at ***ScienceSource***.



(a)



(b)

Figure 12.18 Persons who have full colour vision will see the number 5 in (a) and 74 in (b).

Learning Checkpoint

1. (a) How many degrees of visual field does a legally blind person have?
   (b) How many degrees of visual field does a person with normal vision have?
2. What are two technologies involving the use of a laser that can help people who are losing their sight?
3. Identify one advantage and one disadvantage of being colour blind.
4. What optical technology can help people with dyslexia?

D28 *Inquiry Activity*

Skills Reference 2

SKILLS YOU WILL USE

- Using equipment, materials, and technology accurately and safely
- Communicating ideas, procedures, and results in a variety of forms

Sheep Eye Dissection

Question

How do the various parts of the eye function together to make an image appear on the retina?

Materials & Equipment

- preserved sheep eye
- dissection tray
- dissecting probe
- scissors
- tweezers
- hand lens
- prepared slides of retinal cells
- optional: microscope
- optional: ray box

CAUTION: The scissors and probe need to be handled with care.
If you cut yourself, seek first aid from your teacher.
Keep your hands away from your eyes and mouth.
Wash your hands thoroughly with soap after you finish the activity.
Dispose of all biological material according to your teacher's instructions.

Procedure

Part 1 — External Structures

1. Place a sheep eye in your dissection tray. Rotate the eye until the cornea is facing you.
2. Locate the following on the outside of the eye:
   - fat: yellow tissue that surrounds the eye and cushions it from shock
   - optic nerve: a white cord on the back of the eye about 3 mm in diameter that carries messages between the eye and the brain
   - muscles: reddish or grey flat muscles around the eye used to raise, lower, and turn the eye
3. Examine these structures on the front surface of the eye:
   - eyelids: two moveable covers that protect the eye from dust, bright light, and impact
   - sclera: tough, white outer coat of the eye that extends completely around the back and sides of the eye to protect and enclose it
   - cornea: a clear covering (preservative often makes this appear cloudy) over the front of the eye that allows light to come into the eye
   - iris: round black tissue through the cornea that controls the amount of light that enters the inner part of the eye (may be coloured in humans)
   - pupil: the round opening in the centre of the eye that allows light to enter and whose size is controlled by the iris

Part 2 — Internal Structures

4. Place the eye in the dissecting pan so it is again facing you. Using the tip of your probe, gently pierce the white part of the eye about 1 cm away from the edge of the cornea. Make a hole large enough for your scissors.
5. Using your scissors, carefully cut around the cornea. Try not to disturb the inside of the eye as you cut. Use the edge of the cornea as a guide. Pick up the eye, and turn it as needed to make the cut. Fluid called aqueous humour will come out of the eye as you cut.
   - aqueous humour: fluid found in the space between the cornea and lens that nourishes the cornea and the lens and gives the front of the eye its form and shape
6. Carefully remove the cornea from the front of the eye. Try looking through it. Cut the cornea in half to note its thickness. Observe and record your observations in your notebook.

7. Observe the lens, the iris, and the ciliary muscle at the front of the eye with the cornea removed. Observe and record the shape of the lens. Optional: use a bright ray box to shine light through the cornea and the lens to see the optical effects of their shapes.
   - iris: dark tissue of the eye that contains curved muscle fibres
   - lens: hard, solid structure that can be seen through the pupil
   - ciliary body: black muscle fibres located on the back of the iris that change the shape of the lens
8. Carefully remove the lens and vitreous humour from the eye. Use your tweezers and probe to carefully work around the edges of the lens.
   - vitreous humour: clear jelly-like substance found behind the lens that helps to maintain the shape of the eye and supports the inner structures, such as the retina and the lens.
9. Cut the back of the eye partly away from the iris and ciliary body to expose the retina and the blind spot.
   - retina: tissue in the back of the eye where light is focussed.The surface of the retina is covered with blood vessels that bring oxygen and nutrients to the retina and remove waste. The retina in a living eye is smooth.
   - blind spot: nerve cell fibres carrying impulses from the retinal receptors leave the eye in this region and enter the optic nerve
10. Sketch a labelled diagram of the eye.
11. Dispose of the eye parts and your gloves as directed by your teacher. Follow your teacher's instructions for cleaning your work area.
12. Optional: Use a microscope to observe a prepared slide of retinal cells and look for rods and cones.

Analyzing and Interpreting

13. (a) What differences did you notice between a sheep eye and a human eye?
    (b) What do the differences suggest about a sheep's vision?
14. Draw a labelled diagram showing the structure of the eye.

Skill Practice

15. Show, through a diagram or model, how the flexible part of the eye works to change the ability of the eye to focus.

Forming Conclusions

16. Describe how the various parts of the eye function together to make an image appear on the retina.
17. The eye is a fairly simple structure as compared to a camera, yet it has remarkable abilities. What are some things a human eye (Figure 12.19) can do that a camera cannot do?

Figure 12.19 Human eye, side view

DI Key Activity

CASE STUDY

D29 STSE *Decision-Making Analysis* — Skills Reference 4

SKILLS YOU WILL USE
- Formulating questions
- Evaluating reliability of data and information

Evaluating Laser Vision Correction

Issue

For most people with vision problems, the opportunity to decrease or eliminate dependency on glasses or contact lenses is very appealing. Millions of people have had partial or full sight restored through refractive eye surgery. Are the benefits of the surgery worth the risks?

Background Information

Laser vision correction uses an excimer laser to adjust the focal length of the eye by changing the curvature of the cornea. Excimer lasers apply ultraviolet light of wavelength 193 nm to vaporize tiny amounts of tissue from the cornea.

There are two ways that the laser can be used to correct the curvature (Figure 12.20). One technique is called surface surgery. The surface layer is removed using chemicals, and then the laser is used to remove some tissue just below the surface layer.

Another technique is called flap surgery. Here, the surface layer is left intact. An instrument called a microkeratome is used to cut a thin flap of tissue that includes the surface layer from the front surface of the cornea. This flap is folded back, exposing an inner layer of the cornea. Once tissue is removed with the laser, the flap is returned to its original position.

Refractive eye surgery may not be suitable for patients who:
- are in their early 20s or younger
- have needed a change in their lens prescription during the past year
- actively participate in contact sports, such as boxing, wrestling, and martial arts
- have a history of eye injuries or disease
- have large pupils, thin corneas, inflammation of the eyelids, or previous refractive surgery
- are pregnant or have diabetes

Most patients enjoy problem-free vision as a result of refractive eye surgery. However, some patients do experience problems as a result of the procedure.

A small percentage of patients lose of some of the vision that they already have. Some patients develop visual symptoms, such as severe dry eyes and night vision difficulties due to glare and halos around lights. Other patients experience vision that is undertreated or overtreated so they still need glasses. Some of the results may diminish as people age and their focal length changes. Long-term data are not yet available because the procedures are so new.

Figure 12.20 Refractive eye surgery

Analyze and Evaluate

1. Describe the types of disorders that laser eye surgery is intended to correct.

2. Identify the risks and benefits associated with these surgical procedures.

3. Laser vision correction surgery is advertised in the media (i.e., television, radio, etc.). Describe the effects that media promotion of the surgery may have.

4. Discuss the question "Is laser vision correction surgery safe?" Consider the social, technological, and economic factors that may affect your position.

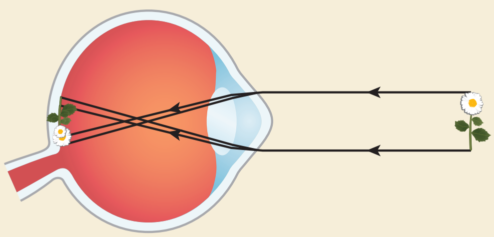
Skill Practice

5. Suppose you had vision problems that could be corrected by laser surgery. How would you decide whether to have the surgery? What would be your main concerns and questions?

12.1 CHECK and REFLECT

Key Concept Review

1. Draw and label an illustration of the human eye from a side view.
2. Your cornea allows light to enter your eye. What are two other functions of the cornea?
3. (a) Compare the pupil to a doughnut hole. In this analogy, what structure in the eye represents the doughnut?
   (b) How does this structure work?
4. (a) What is the shape of your lens when viewing distant objects?
   (b) What is the shape of your lens when viewing nearby objects?
5. What is the function of the retina?
6. What do photoreceptors detect?
7. What does the optic nerve connect?
8. Describe how improper focussing by the eye causes:
   (a) far-sightedness
   (b) near-sightedness
9. (a) What type of lens should a person who is far-sighted use?
   (b) What type of lens should a person who is near-sighted use?
10. What condition is shown below?



Question 10

11. (a) Describe a potential benefit of laser eye surgery.
    (b) Describe a potential risk of laser eye surgery.
12. (a) Can a legally blind person see? Explain.
    (b) Use your own words to write a definition of blindness.
13. How is colour blindness different from colour vision deficiency?
14. What is the most common form of colour vision deficiency?

Connect Your Understanding

15. If you wanted to use a friend's eyeglasses as a magnifying glass, would you ask someone who is far-sighted or someone who is near-sighted?
16. (a) How are rod cells and cone cells similar?
    (b) How are rod cells and cone cells different?
17. What does a laser surgery method of vision correction have in common with wearing glasses to correct vision?
18. Write an explanation for each of the following audiences on how the human eye works. You may wish to include a labelled diagram.
    (a) your teacher
    (b) a kindergarten student

Reflection

19. What can you explain about the eye and its capabilities that you were not able to before reading this section?

For more questions, go to *ScienceSource*.

12.2 Technologies That Use Light

Here is a summary of what you will learn in this section:

- Cameras collect and focus light in order to form an image.
- Microscopes are made of two convex lenses that are arranged to make magnified images of objects.
- Refracting telescopes use lenses to collect and focus light, whereas reflecting telescopes use mirrors for the same process.
- A telephoto lens magnifies a distant object. A wide-angle lens provides a large field of view.

Figure 12.21 An amateur astronomer uses a telescope to view the Milky Way galaxy.

The Invention of the Telescope

Some of the most fascinating discoveries of the last few hundred years have come about thanks to astronomers observing the sky with telescopes (Figure 12.21). Telescopes are fairly common now as shown in Figure 12.22, but when the telescope was first invented its existence was kept secret.

The first documented invention of a telescope was by the Dutch spectacle-maker Hans Lippershey. When one of his apprentices held up two lenses in front of his eyes, he was surprised to find that distant objects appeared even closer than when looking through only one lens. Lippershey placed the lenses at either end of a tube and in 1608 took his invention to the Dutch government. The Dutch government realized that telescopes could give a great advantage in warfare, so they decided to keep the invention a secret. The secret was not well kept, however, and within a year, lens crafters all over Europe were building and selling small telescopes.

Figure 12.22 Coin-operated telescopes are available in some scenic locations for the public to use.

Hans Lippershey himself helped spread the news of the telescope to the most famous and productive scientist of his time — the Italian astronomer and physicist Galileo Galilei. Galileo obtained one of Lippershey's telescopes and within a few months improved the design and built what was then the most powerful telescope in the world, able to magnify objects up to 30 times. He turned his telescope to the sky and became the first person in history to see mountains on the Moon.

Technology Development Continues

Galileo also discovered that four moons orbited the planet Jupiter. His discovery provided evidence that the Sun was the centre of the solar system rather than Earth. This started a race to build the best telescope possible. Larger lenses were used to capture more light and increase magnification. Thin lenses have better optical properties than thick ones but need to be spaced farther apart, so telescopes became both wider and longer. The largest early telescopes were much too large to hold, and in some designs one lens would be mounted on the roof of a building while the other lens was placed on the ground. Many sizes, shapes, and arrangements of lenses were tried, but eventually every design came upon the same insurmountable problem. Lenses refract different colours of light differently. Just as a prism can split sunlight into a rainbow, even the best lenses refract different colours of light in different ways. For example, this resulted in the image of a planet being surrounded by circles of different colours.

A new design was needed. By the late 1700s, another great scientist, Isaac Newton, had designed a telescope in which the large convex lens normally placed at the front of the telescope was replaced with a large concave mirror placed at the back of the telescope (Figure 12.23). This type of telescope was difficult to build because the technology needed to grind a mirror to the correct shape was not well developed. However, the advantages were great because mirrors were much lighter than lenses and they did not absorb some of the light, as big lenses had a tendency to do. This same design is used by all the largest and most powerful telescopes today.

Figure 12.23 Sir Isaac Newton's reflecting telescope

D30 *Quick Lab*

Extending Human Vision

Purpose

To appreciate the value of extended vision

Procedure

1. Choose a photograph in this student book that was taken using a telescope and that you think reveals important information about its subject.
2. Choose a photograph in this book that was taken using a microscope and that you think reveals important information about its subject.
3. Choose your favourite photograph in this student book.
4. Share your choices with members of your group Discuss your reasons for each of your choices.

Question

5. Consider all the choices your group has presented. Which image gives information that has had the most important effect on society? Explain why.

Cameras

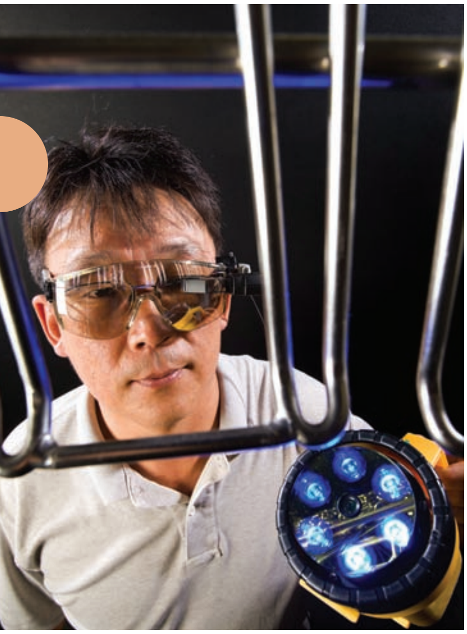


Figure 12.24 This portable imaging device is equipped with a head-mount display for inspecting the sanitation of food-processing equipment.

Our view of ourselves, our planet, and our universe has grown enormously by learning how to extend our vision. Laser light and fibre optics have allowed us to transmit light within the human body. Microscopes have allowed us to see a world of structures and organisms that was completely unknown just a few hundred years ago. Using telescopes, we have observed stars exploding in deep space, temporarily outshining nearby galaxies containing billions of stars. We can record images of all these very large and very small subjects using cameras.

The recent increased availability of small, inexpensive, and low-power cameras has had important social effects. Because they are incorporated into cellphones and mobile digital devices, cameras can be taken almost anywhere and images can be transmitted almost instantly around the world. This widespread use of cameras has raised concerns about privacy, but it has allowed easier communication between communities of people in different locations.

Cameras are also used in industrial applications, such as automated vision systems to ensure quality control (Figure 12.24). For example, the Canadian Food Inspection Agency uses colour digital photography to monitor food colour and compare it with the colours of good quality food. If the colour of the food product does not match an acceptable stored value, an alarm goes off and the food product is manually inspected.

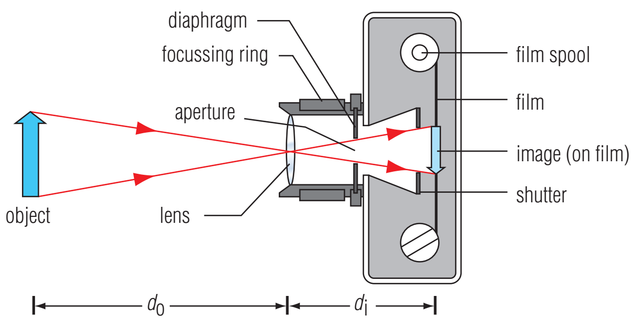


Figure 12.25 The parts of a simple camera that uses film

Parts of a Camera

A **camera** is basically a lightproof box with a lens at one end to form a real, inverted image on a light detector or light-sensitive plate or film (Figure 12.25). For a distant object, the image distance d_i is equal to the focal length of the lens. For nearer objects, the lens must be moved farther from the light detector so that the image is still focussed. A **shutter** controls the length of time light is allowed in. The **diaphragm** is the part of the camera that controls the aperture. The **aperture** is the opening that the light passes through, much like how the iris controls the pupil in the human eye. A large aperture is helpful in low light situations or when the subject of a photograph is far away. The larger the aperture, the greater the amount of light that can be collected by the camera.

Suggested Activity
D32 Inquiry Activity on page 493

Suggested STSE Activity
D33 Decision-Making Analysis on page 494

Almost all cameras use a convex lens to refract light rays onto a light detector, such as a charge-coupled device (CCD), that records the image. The image is usually recorded digitally and can be produced as a paper photograph, as an image for display on a monitor, or as a moving image or video. The image is stored on a memory chip and can be transferred to a computer, printer, or other electronic device.

Types of Lenses

The farther away an object is, the dimmer it is and the fewer the light rays that can reach the camera. A **telephoto lens** increases the amount of light that is collected and magnifies a distant object. A telephoto lens has a long focal length, which is why it protrudes so far in front of the camera (Figure 12.26).

The opposite of a telephoto lens is a **wide-angle lens**, which captures a wider angle of view (Figure 12.27). The shape of a wide angle lens is more spherical and has a shorter focal length than a telephoto lens. Cellphone cameras usually have a wide-angle lens.

Figure 12.26 A telephoto lens magnifies distant objects.

Figure 12.27 A photograph of the aurora borealis taken using a wide-angle lens

Digital Images

When the light detector in a digital camera records an image, it does so by registering different parts of the image on many thousands or millions of different detectors. Each tiny area of the image is assigned a single colour and brightness (Figure 12.28). These tiny picture elements are known as **pixels**. When the pixels are combined, an apparently continuous image is produced. The greater the number of pixels, the more closely the image resembles the original object.

WORDS MATTER

"Pixel" is formed from pix, which is a slang expression meaning pictures, and el, which is short for elements.

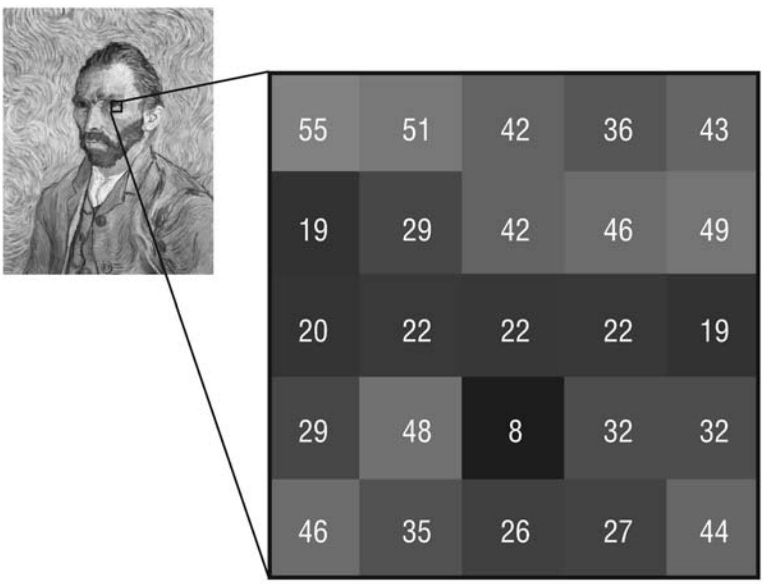


Figure 12.28 A digital image is made by combining thousands of individual pixels.

Digital Image Manipulation

Digital cameras can produce a range of optical effects, from highly detailed and realistic to manipulated and abstract. Because every image is composed of pixels, each of which is stored as a series of numbers, it is possible to manipulate the images by using software to change the values of the numbers stored for every pixel. For example, sometimes people's eyes appear bright red in photographs (Figure 12.29). This is because light from the camera flash passes into the eye, reflects off the red blood vessels inside of the eye, and then passes out again through the pupil. The red in the photograph can be removed using image editing software.

Image editing software allows many changes and improvements to the images captured by a camera. You can brighten the colours, remove unwanted objects in the photograph, sharpen or soften images, change colours, or even take objects from one photograph and add them to another. For example, you can take a photograph of yourself and insert it into a photograph of a scene from a foreign land that you have never visited. All of these changes allow increased creativity in making images more realistic or less realistic. However, manipulating images also raises concerns when the changes are applied to images in mass media such as magazines and newspapers.

Suggested STSE Activity

D34 Decision-Making Analysis on page 495

Figure 12.29 A digital image can be modified using software.

Learning Checkpoint

1. What is the difference between a shutter and an aperture?
2. (a) What is an advantage of widespread camera use?

   (b) What concerns have been raised over widespread camera use?
3. How does the focal length of a wide-angle lens compare to the focal length of a telephoto lens?
4. How is a digital image produced from pixels?

Microscopes

Some of the most important advances in health care during the last few hundred years have been the result of our ability to view the microscopic world, both directly through microscopes and indirectly through images. One of the first discoveries made using a microscope was that there were living things so tiny that they could not be seen with the unaided eye. The discovery was made by Antonie van Leeuwenhoek, a Dutch amateur scientist in the 1600s. Although his microscopes were very simple in design and had only one lens, van Leeuwenhoek used them to look at things like pond water, blood, and the plaque from his own teeth. What he saw astounded him. He wrote about his discoveries of "little animalcules" which were really the first descriptions of microscopic items such as bacteria, algae, and red blood cells. Van Leeuwenhoek's discoveries surprised the scientific world. Up until then, people had no idea there were organisms so small that you could not see them.

These discoveries confirmed one of the single most important health improvements in human history: the importance of washing hands. Prior to these discoveries, people did not realize that doctors moving from patient to patient in hospitals were spreading micro-organisms. The progress of entire plagues could be checked simply by having good sanitation.

WORDS MATTER

The suffix "-scope" is derived from the Greek verb meaning to view. In modern usage, a scope means an instrument for viewing. The prefix "micro-" means tiny, "tele-" means distant, and "peri-" means around or above. A microscope is for viewing tiny objects; a telescope is for viewing distant objects; and a periscope is for viewing objects above the scope.

Parts of a Microscope

In a **compound microscope**, a pair of convex lenses causes a small object to appear magnified when viewed through the eyepiece. The specimen is placed on a glass slide and then illuminated with a light source. Light travels through the objective lens, which is a convex lens at the bottom of the tube close to the specimen. Like a simple magnifying glass, the lens forms an upright enlarged image of the object when the object being viewed is less than one focal length from the lens. By using a second convex lens in the eyepiece, a magnification of hundreds or thousands of times can be achieved. Notice in Figure 12.30 that the light rays from the object converge inside the microscope and then diverge again. This crossing over of the light rays causes the image to become inverted. As a result, when you look through a microscope, the image is upside down.

Another type of microscope that uses light is the confocal microscope, which uses a laser beam to light the specimen. The image of the specimen is then digitally enhanced so it can be viewed on a computer monitor.

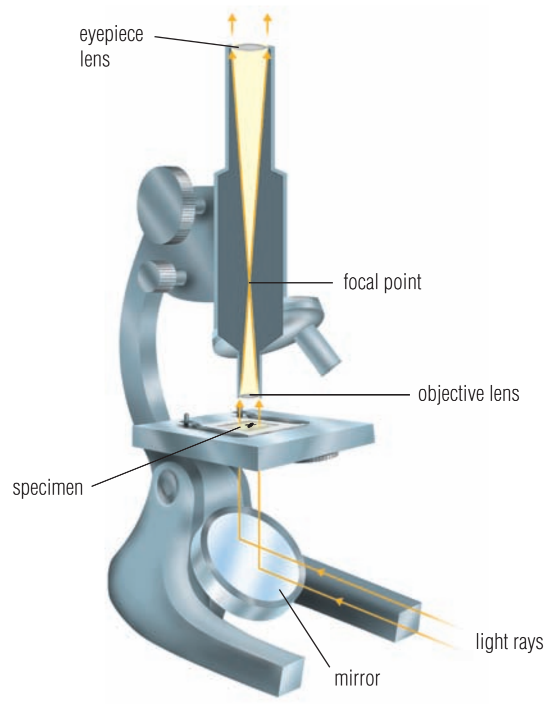


Figure 12.30 A compound microscope allows you to see great detail by combining the power of at least two lenses.

During Writing — Thinking Literacy

Evaluating Information

Background information is never the whole story when you are analyzing an issue or situation. You need to make a final judgement or evaluation of the situation by telling your readers what is most important and why they should care about the topic. Make recommendations about what should be done.

Telescopes

A **telescope** is an optical device that provides enlarged images of distant objects. The lenses and mirrors in a telescope collect light from distant objects and focus it so the objects can be viewed directly or recorded using a charge-coupled device. There are two main reasons why it is difficult to see an object that is far away. One reason is that any distant object appears very small. But there is another equally important reason, which is that the farther away an object is, the dimmer it becomes. Recall that we see an object because light rays radiate off it and pass into our eyes. The more light rays that reach our eyes, the brighter the object appears. At greater distances, fewer light rays reach our eyes.

A telescope uses either a concave mirror or a convex lens that is much larger than human eyes so that it can gather more light. This is why some telescopes are so large — not to magnify better, but to collect more light. There are two main types of telescopes: refracting telescopes and reflecting telescopes.

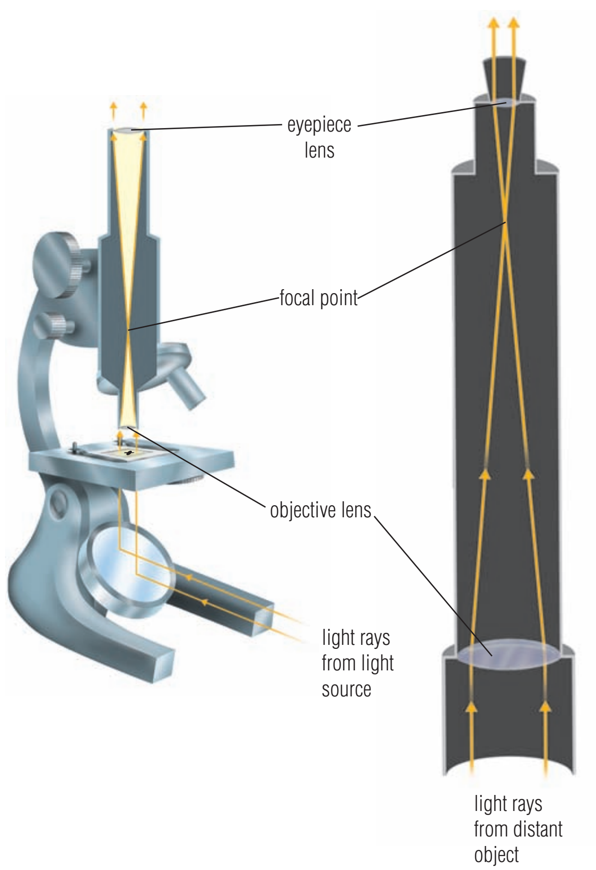


Figure 12.31 A microscope and refracting telescope have a similar design.

Refracting Telescopes

A **refracting telescope** is similar in design to a microscope, in that they both have two lenses, one on each end of a long tube. However, unlike a microscope, the objective lens in a telescope is the larger lens. Because the object viewed with a telescope is far away, the objective lens has a very long focal length. This is more suitable for focussing light rays that are almost parallel when they strike the lens, which is how light rays arrive at the telescope when coming from an object a great distance away. This also explains why refracting telescopes can be very long. The rays refracted by the objective lens need a long distance before they converge, as in the diagram in Figure 12.31.

Refracting telescopes are often used by amateur astronomers because of their portability. However, refracting telescopes are rarely used for astronomical research because very large lenses are heavy and can sag under their own weight. Another disadvantage is that lenses absorb some of the light that passes through them.

Binoculars

Using a combination of several mirrors and lenses, it is possible to make a refracting telescope more compact. For example, **binoculars** are two short refracting telescopes attached together as shown in Figure 12.32. The two telescopes are made shorter by using prisms inside that act as mirrors to redirect the path of light rays.

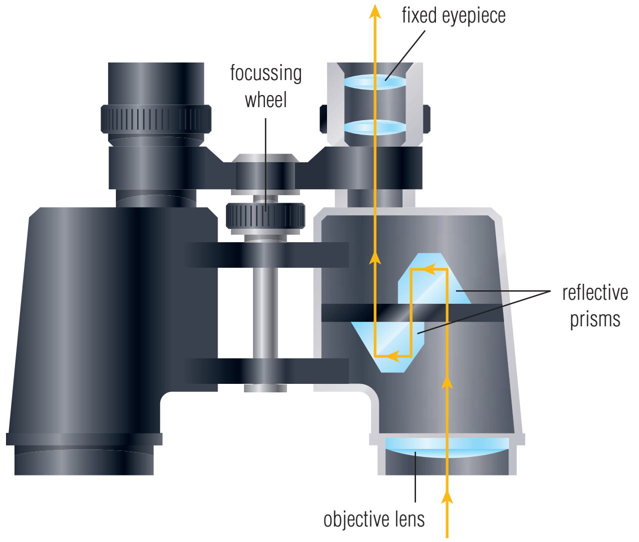


Figure 12.32 Binoculars have two reflective prisms on either side to make the arrangement more compact.

Reflecting Telescopes

The largest telescopes are built using mirrors because mirrors do not absorb light. In a **reflecting telescope**, light enters from one end of a tube and then reflects off of a concave mirror toward a small plane mirror. This small mirror directs the light into an eyepiece, camera, or other instrument (Figure 12.33).

One of the largest telescopes, the Gemini North telescope is located in Hawaii and is operated by Canada and six other countries The Gemini North telescope has a flexible mirror 8 m in diameter that can be adjusted in microseconds to correct for disturbances in the atmosphere that would cause blurry images (Figure 12.34). Together with a second telescope, called Gemini South, located in Chile, the entire sky can be viewed.

Figure 12.34 The Gemini North telescope in Hawaii is one of the largest telescopes in the world.

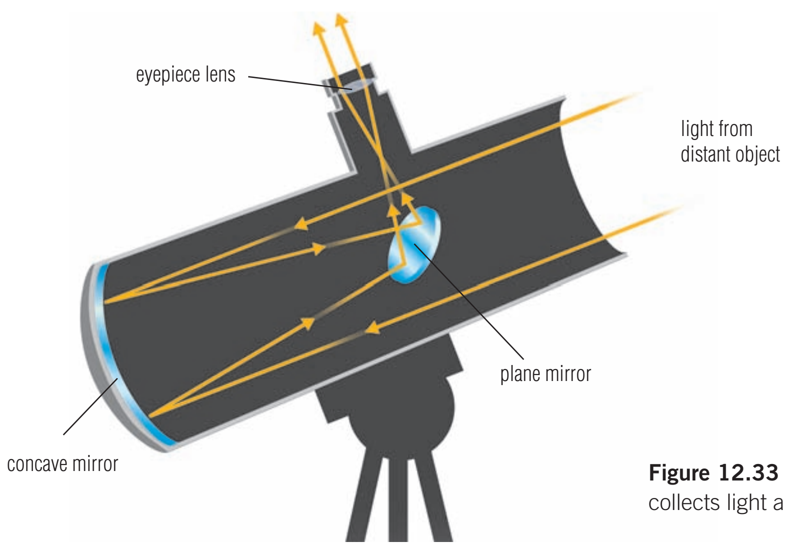


Figure 12.33 In a reflecting telescope, a large concave mirror collects light and causes it to converge.

Learning Checkpoint

1. What lenses are used in a compound microscope?
2. Why is the image you view through a microscope upside down?
3. Why are some telescopes very large?
4. What are two main types of telescopes?
5. How are binoculars made more compact than telescopes?

Lasers

WORDS MATTER

The word "laser" is an acronym that stands for "**l**ight **a**mplification by **s**timulated **e**mission of **r**adiation."

A **laser** is an optical device that produces a form of light in which all the light rays are almost perfectly parallel, all have the same wavelength, and all of the wave crests and troughs are exactly lined up. Laser light is very different from incandescent light, which is usually a jumble of different wavelengths with the wave crests and troughs arranged randomly (Figure 12.35).

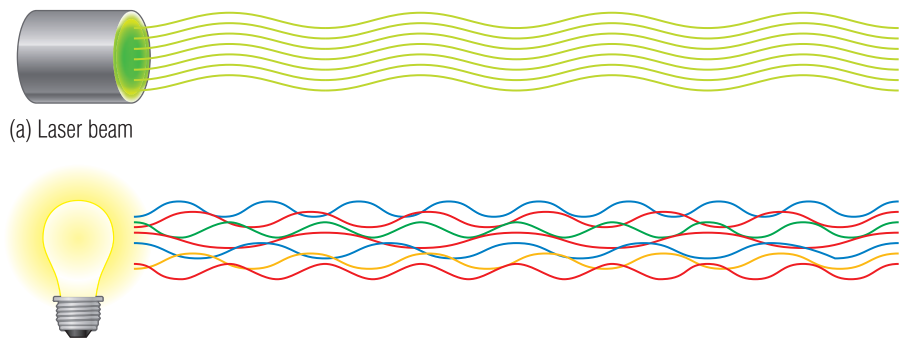


Figure 12.35 (a) In laser light, the light waves are parallel, have the same wavelength, and have wave crests and troughs aligned. (b) In ordinary light, different wavelengths (colours) of light are combined randomly.

Laser light is used in communications, consumer electronics, bar code readers, and DVD players, where information on the DVD is encoded in a manner similar to bar codes but in a microscopic size. You may also be familiar with lasers used in entertainment (Figure 12.36).

Lasers used in different applications vary tremendously in brightness. However, all lasers are bright enough to do permanent damage to the retina of your eye, which is why you should never look directly into a laser beam, even briefly. The brightness of a laser depends on the power used to generate the light, the colour of the light, and how well it remains in a tight beam. Very little energy is needed to operate lasers compared to other forms of light production. For example, an outdoor laser show can shoot bright laser beams using less energy than is needed in a standard household light bulb. The difference between the two is that all the energy in a laser is concentrated into a single beam. Stadium lasers are safe to view because they are kept at a distance and not directed straight into an audience.

Figure 12.36 Lasers are often used in light shows.

Lasers in Medicine

Lasers are used as a diagnostic tool in medicine to detect cancer. Many forms of cancer produce chemicals that leave the cancer cells and enter the bloodstream. By taking a sample of blood and shining laser light through the blood, it is now possible to detect certain kinds of cancers before they cause symptoms or grow large enough to be detected by an X-ray.

Colours of Laser Light

Because our eyes are more sensitive to green light than red or blue, a green laser beam appears brighter to us than a laser beam of a different colour (Figure 12.37). Although laser beams are more tightly concentrated than ordinary light beams, they still spread out. In fact, a laser beam may be several kilometres in diameter by the time it reaches the Moon. Astronauts from the Apollo missions left mirrors on the Moon. The mirrors are used with lasers to measure the distance between Earth and the Moon.

670 nm	diode
650 nm	diode
635 nm	diode
633 nm	helium-neon
568 nm	krypton
532 nm	diode
514 nm	argon
488 nm	argon
473 nm	diode
458 nm	argon
416 nm	krypton
410 nm	diode

Figure 12.37 Some common colours of laser light. The column on the left shows the wavelengths of light produced by the various types of lasers listed on the right.

Photonics

In the wave model of light, different colours of light have different wavelengths. Another way of modelling how light travels is by thinking of light as a series of many tiny packets of energy called **photons**. In this model, the colour of light is related to the amount of energy carried by each photon. It has been found, for example, that a photon of blue light carries more energy than a photon of yellow or red light. A photon of ultraviolet light carries even more energy than a photon of blue light, which is why ultraviolet light can damage skin, whereas blue, yellow, or red light cannot. Both the wave and the photon models of light each account for some properties of light. However, both models are needed to account for all of the properties.

Technologies that make use of the way in which light travels as photons are called **photonics**. Photonic technologies are used in many applications including laser technologies, digital cameras, solar energy generation, and computers with components that use light instead of electricity.

Take It **Further**

Canadian scientists are guiding the building of the world's largest optical telescope, the Thirty Meter Telescope (TMT). The 30-m mirror in the telescope will actually be made of many smaller mirrors. and the telescope will be nearly 100 times more sensitive than existing telescopes. Find out more about Canada's role in building the TMT. Begin your research at ***ScienceSource***.

Digital Cameras

The widespread availability of tiny, inexpensive still and video cameras has occurred partly due to photonics technologies in image capture. Just as a solar cell absorbs photons of light to produce electricity, millions of tiny, individually wired cells can be grouped together on a grid to detect many different photons at one time. Combining all of these detectors at once creates an image. The most common form of detector is a charge-coupled device (Figure 12.38).

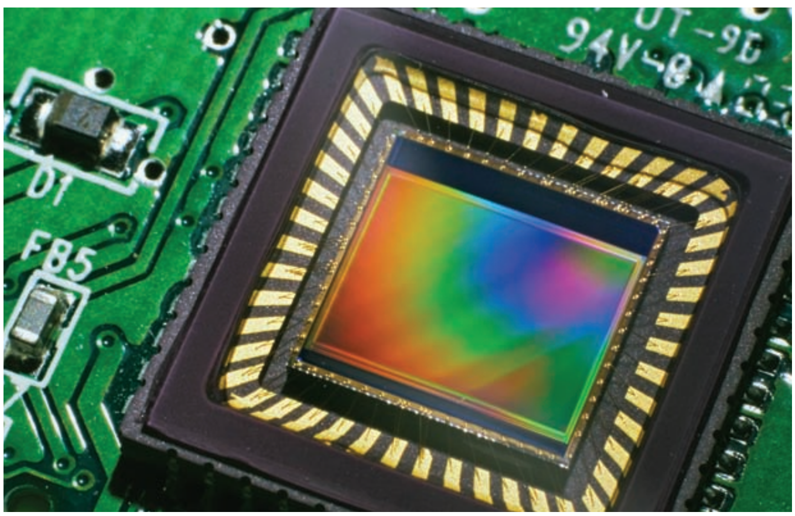


Figure 12.38 A charge-coupled device (CCD)

Figure 12.39 Long rows of solar cells

Solar Cells

Solar cells convert sunlight directly into electrical energy (Figure 12.39). When a photon of sunlight is absorbed by an atom of a metal, such as lithium, an electron within the atom receives the energy of the light. This permits the electron to move away from the atom along a circuit. The flow of electrons in the circuit is electric current.

Solar cells have existed for many decades. Recent emphasis on renewable and clean energy production has inspired intensive research into new and widespread applications for high-efficiency solar cells.

Optical Computers

Traditional computers use electronic components to perform their functions through the movement of electrons in electric circuits. In an optical computer, photons take the place of electrons and optical switches and components do the calculating and other functions within the central processing unit of the computer. Optical computing is currently in an intensive research and development phase. Optical computers are expected to be much smaller but also to operate much faster than electronic devices.

D31 **STSE** ***Science, Technology, Society, and the Environment***

Digitally Edited Photographs

Before photographs appear in a newspaper or magazine, a photo editor removes any "noise" including dust or distracting elements. Removing a distracting element might mean taking out a tree branch that is obscuring part of a statue, or it might mean removing a building or cars from the background. Photographs of people are often airbrushed to smooth out skin features. Sometimes, an editor also adds elements to a photograph, such as increasing the size of a crowd gathered to watch an event or adding fireworks to a night sky. These changes mean that the photographs you view in a magazine or newspaper may no longer be accurate portrayals of the events they capture.

1. Take the approach that digital editing is acceptable. Develop an argument that supports your position from the point of view of:

(a) the editor of a news magazine

(b) the editor of a fashion magazine

2. Take the approach that digital editing is only sometimes acceptable. Explain when it should be allowed.

D32 *Quick Lab*

Disassembling a Disposable Camera

Purpose

To disassemble a disposable camera to identify its optical systems

Materials & Equipment

- non-flash disposable camera
- small tool set
- parts tray

CAUTION: Do NOT use a camera equipped with any type of flash or power source.

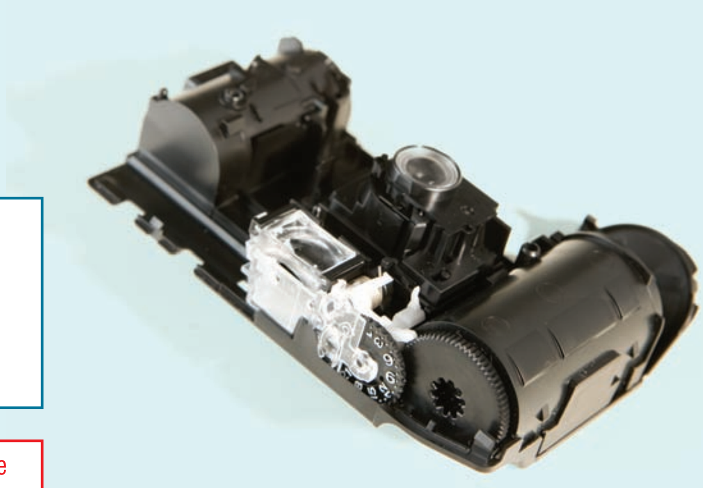


Figure 12.40 The interior of a disposable camera

Procedure

1. Perform a safety check before starting your disassembly. Make sure you are wearing eye protection. Inspect the camera carefully for a flash. If it has a flash, DO NOT proceed. Return the camera to your teacher. If your camera has an outer paper and/or plastic covering, remove it. Inspect the camera carefully, looking for power sources such as batteries. If you see a battery, DO NOT proceed. Return the camera to your teacher.
2. Find the screws or clips that hold the case together, and open the case (Figure 12.40).
3. Identify optically important parts such as the shutter and lens. Observe and record the kind of lens. Notice how it is positioned with respect to the film so that it will produce an inverted image. See Figure 12.25 on page 484.
4. Carefully take the camera apart. Organize your camera parts to show how the optically important components collect and convert light to produce a focussed image.
5. Organize all other components to show how they encase the optical parts while permitting access to the interior of the camera.

Questions

6. (a) What parts of the camera are optically important?

   (b) What parts are not optically important?
7. (a) Which parts of the camera are similar in function to the eye?

   (b) Which parts of the camera are different in function from the eye?
8. (a) Describe how the camera could be used to make a good model for the eye.

   (b) Describe the limitations of the camera as a model for the eye.
9. What other uses can you think of for the film?

D33 STSE *Decision-Making Analysis* Skills Reference 4

SKILLS YOU WILL USE

- Gathering, organizing, and recording relevant information from research
- Drawing conclusions

Single-Use Cameras: Useful Convenience or Wasteful Extravagance?

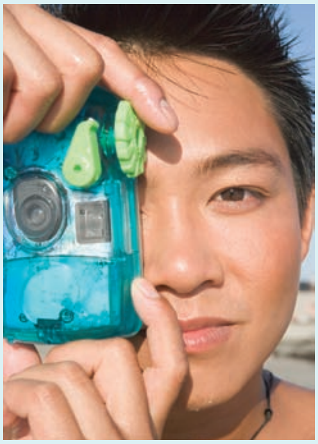


Figure 12.41 Single-use cameras are also called disposable cameras. This single-use camera is specially made for taking photographs underwater.

The Issue

Camera manufacturers have found specialty markets for devices called single-use cameras. In a single-use camera, a small number of photos are taken and then the camera is recycled (Figure 12.41). For example, some people store a single-use camera in their car. If there is a collision, they will be able to make a visual record as evidence in a legal proceeding. Are single-use cameras useful to society? Or are they a wasteful extravagance because of the amount of energy involved in producing and then immediately recycling them after one use?

Background

Inexpensive, good quality digital cameras designed for long-term use are widely available. These cameras are very versatile. They can display the images saved in their memory. Uploading images to a computer or the Internet for display or printing is relatively easy. Yet, despite the many conveniences of the standard digital camera, manufacturers have found that there is also a market for single-use cameras. Single-use cameras are designed for people who might be without a regular camera. These cameras are useful while on vacation or participating in some form of recreation where an expensive camera might be at risk of damage, such as whitewater rafting.

Some single-use cameras are designed for specific applications such as underwater use while snorkelling or swimming. Not only are they waterproof, they are specially adapted for light conditions under water. Other kinds of specialized single-use cameras are available for indoor/low light conditions, night photography, and wide-angle scenery shots. Another application is at celebrations, where the hosts pass a number of cameras out among the guests. At the end of the event, the cameras are collected and the photos are assembled as a record of the event.

Single-use cameras are convenient for someone who already owns a good quality digital camera and does not wish to buy a second one. There is even an application available in a single-use camera that is not available with traditional ones. Some single-use cameras can produce a hard copy of a photograph right on the spot — at the beach, the party, or wherever.

Critics of single-use cameras point out that recycling is only one part of an overall strategy of reduce, reuse, and recycle. Even recycling costs energy and other resources. Another criticism is that the research into disposable cameras might be better spent on research into making cameras more rugged and less prone to damage.

Analyze and Evaluate

1. Read the above background information. Create a chart comparing the advantages and disadvantages of single-use cameras compared to standard multi-use digital cameras.

2. ***ScienceSource*** Research recent developments in the use and recycling of single-use cameras.

Skill Practice

3. What is your conclusion about whether single-use cameras are a useful convenience or an extravagant waste of money, energy, and resources?

DI Key Activity

D34 STSE Decision-Making Analysis

Skills Reference 4

SKILLS YOU WILL USE

- Thinking critically and logically
- Communicating ideas, procedures, and results in a variety of forms

Visual Recording Devices and Privacy

Issue

Does the widespread use of visual recording devices infringe on people's privacy?

Background Information

You are going out with friends for the afternoon. First, you stop at an automated teller machine. While you make your transaction, your actions are recorded on a security camera in the machine. Then, you catch a bus to go to the city park to meet your friends. A camera installed above the driver captures your image as you step into the bus. When you arrive at the city park to meet your friends, you wait next to a statue in the centre of the park. A group of tourists comes by and they all take photos of the statue — and you. A mother is playing with her children close by and recording them on her video camera. Sometimes, the children play close by you and you are included in the recording. When your friends finally arrive, they take out their cellphones and everyone squeezes together to get into one photograph. The next day, your friend posts the image on her website.

Cameras have evolved to become smaller, easier to transport, and able to produce higher quality images. We can take them almost anywhere and use them almost anytime (Figure 12.42). Security cameras record transactions in stores and are used by police and security personnel to identify people who enter and exit buildings (Figure 12.43). Video cameras are installed in some schools to record activities in the classrooms and halls. Cameras installed on satellites, airplanes, trees, and road signs can be used to track vehicles on highways. Your friend with a video camera or cellphone might record events at a party and then later post the recording on the Internet.

Photographic images are used for a wide range of purposes that benefit society. But what are the rights of the person being photographed? When is camera use an invasion of privacy? Should there be limits to when and how cameras can be used?

Analyze and Evaluate

1. ***ScienceSource*** Your task is to choose one side of the argument and research the issue. You will present your findings as a class presentation. Your teacher will provide more details about how to present your information.
2. You may wish to interview friends and family members to gain their perspectives.
3. Sort the information according to usage of images: culture, education, security, policing, entertainment, and the environment.

Skills Practice

4. **Web 2.0** Develop your research as a Wiki, a presentation, a video, or a podcast summarizing your opinion. For support, go to ***ScienceSource***.

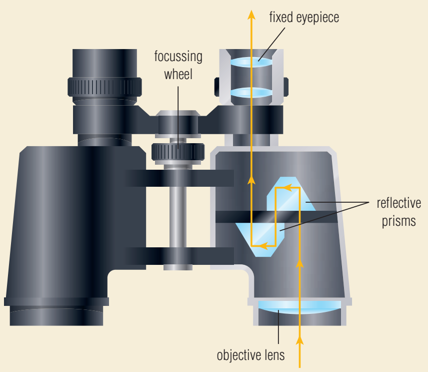
Figure 12.42 You can transmit an image around the world almost instantly.

Figure 12.43 A video surveillance camera

12.2 CHECK and REFLECT

Key Concept Review

1. How are cameras used in food inspection?
2. What is the relationship between the size of the aperture and the amount of light that can be collected by a camera?
3. How is a telephoto lens different from a wide-angle lens?
4. How are digital images manipulated?
5. What are two reasons why it is difficult to see something that is far away?
6. Why was the discovery of microbial life forms important for advancement in public health?
7. Describe the arrangement of lenses in a microscope.
8. Use a ray diagram to help you explain the path of light through a microscope.
9. Which type of telescope is closest in design to a microscope?
10. What is the difference between a reflecting telescope and a refracting telescope?
11. Why is a reflecting telescope better for astronomical observations than a refracting telescope?
12. What other optical device do binoculars closely resemble? Explain.



Question 12

13. List three ways that laser light is different from ordinary light.
14. What are three uses of laser light?
15. Why should you never look directly at a laser beam?
16. Why does a green laser beam seem brighter to us than a laser beam of another colour?
17. What is the name given to individual packets of light energy?
18. What is photonics?
19. What are four applications of photonics?
20. What is a photon?

Connect Your Understanding

21. How has accessibility to optical technologies such as telescopes and microscopes affected our perception of the natural world?
22. What are some ways that the increased use of cameras has affected society?
23. What areas of photonics will likely become even more useful in addressing environmental needs related to energy and people's health?
24. What areas of photonics will likely become even more useful in addressing societal needs in the area of information and community building?
25. What are five careers based on the optics discussed in this section?

Reflection

26. (a) Describe your opinion about widespread camera use as a result of reading this section.
    (b) If your opinion changed while reading this section, explain how and why it changed.

For more questions, go to *ScienceSource*.

Jay Ingram is an experienced science journalist, author of *The Daily Planet Book of Cool Ideas*, and host of *Daily Planet* on Discovery Channel Canada.

A Wall of Water?

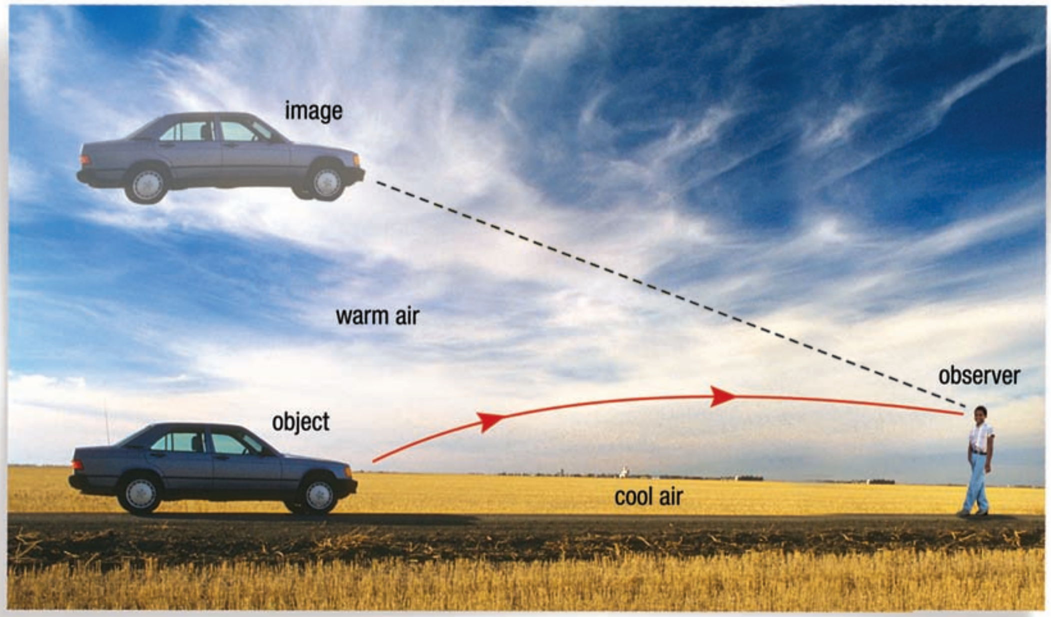


Figure 12.44 A layer of warmer air above a layer of cooler air can cause light to refract and create a mirage.

Things are not always what they seem. As you drive along the highway on a hot summer day, the distant pavement looks wet. But when you get there, it is perfectly dry. Why? Light travels through layers of air of different temperatures; when a highway is heated by the Sun in summer, the highway warms the air just above it. Light travelling down toward the pavement then curves up as it travels through the warm air. The result is that we see a mirage — an image of the sky, superimposed on the road.

Sometimes, the air close to the surface of Earth is cooler than the air above it. In this case, the light that is reflected from an object located on the surface gets refracted and appears to come from a location above the horizon, as shown in Figure 12.44. This type of mirage is called a superior mirage.

A superior mirage could be spectacular over the ocean. A scientist named Waldemar Lehn at the University of Manitoba thinks that Viking sailors crossing the Atlantic Ocean a thousand years ago might have been tricked by a superior mirage into thinking they had entered an oceanic whirlpool. Viking writings describe sea fences that were "higher than lofty mountains."

Imagine you are on a Viking ship crossing the dangerous ocean south of Greenland. The air around you is cold, but above it lies a layer of warmer air. Light always bends towards the colder air. That means that light streaming in your direction from the horizon would curve down, and you would actually be able to peek over the horizon.

Not only would you be able to see much farther, but in extreme cases the actual horizon would seem to rise up — all around you. You might think you had just blundered into the middle of a gigantic whirlpool and you were surrounded by a terrifying wall of water on all sides.

Question

1. How would an understanding of optics have helped early explorers such as the Vikings?

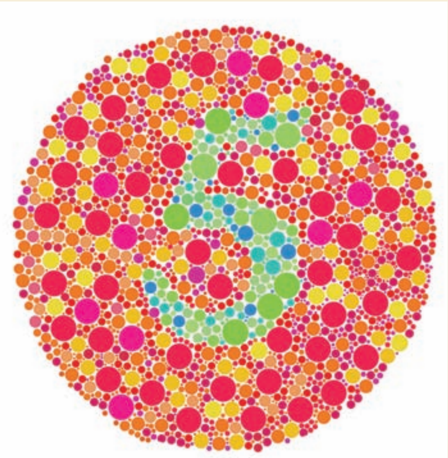
12 CHAPTER REVIEW

ACHIEVEMENT CHART CATEGORIES

k Knowledge and understanding
t Thinking and investigation
c Communication
a Application

Key Concept Review

1. Draw and label the human eye:
   (a) from a side view k
   (b) from the front view k
2. Describe how the human eye accomplishes its task of collecting the right amount of light. k
3. State the two structures that refract light as it enters the eye. k
4. Describe what occurs in each of these conditions and how the condition is treated using lenses.
   (a) near-sightedness k
   (b) far-sightedness k
   (c) astigmatism k
5. Explain the term "legally blind." k
6. What are two technologies that use laser light to help restore vision? k
7. What happens during a retinal implant? k
8. What is colour vision deficiency? k
9. What lack in the eye causes the inability to see the number 5 in the circle below? k



Question 9

10. How do eyeglasses with colour filters help people with dyslexia to read? k
11. (a) What type of lens is usually found in a camera, concave or convex? k
    (b) Where is the image formed in a camera? k
12. How are images taken through a telephoto lens different from images taken through a wide-angle lens? k
13. (a) What is a pixel? k
    (b) How are pixels used to make a photographic image? k
14. How is a digital image manipulated? k
15. (a) Who discovered the first microscopic creatures? k
    (b) How did this discovery benefit society? k
16. Describe the arrangement of lenses in a compound microscope. k
17. Describe an advantage and a disadvantage of the design of a refracting telescope over a reflecting telescope. k
18. Describe the arrangement of mirrors and lenses in a reflecting telescope. k
19. (a) Why do lasers require comparatively little energy to operate? k
    (b) Why is it dangerous to look directly at a laser beam? k
20. (a) How do solar cells make use of photonics? k
    (b) How do optical computers make use of photonics? k

Connect Your Understanding

21. State a benefit and a limitation of each of the following devices. a

(a) microscope

(b) refracting telescope

(c) reflecting telescope

(d) binoculars

(e) camera

22. What could happen to your sight if the muscles surrounding the pupil did not work properly? t

23. Why might the Canadian Ophthalmological Society suggest different colour vision standards for drivers of personal vehicles, taxi or bus drivers, and emergency vehicle drivers? a

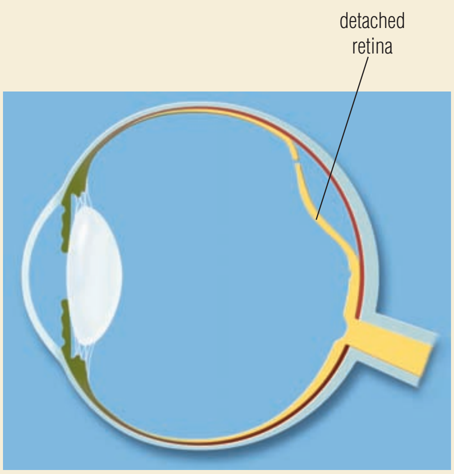
24. (a) Make a chart that lists the parts of the eye and the parts of a camera and their function. k

(b) What do the camera and the eye have in common? t

(c) How are the camera and the eye different? t

25. "All cats are grey in the dark." Using your knowledge of how the eye works in low light, explain why this expression is true. t

26. It is possible for the retina to detach from the back of the eye. What would the effect of retinal detachment be on someone's vision? t



Question 26

27. How can we perceive hundreds of different colours when the cones in the retina are sensitive mostly to the three primary colours? t

28. Describe how a person with blindness would need different techniques or technologies to carry out daily living as compared to a person who is colour blind. t

Reflection

29. Describe what you found most challenging in learning about how optical devices and the human eye work together. c

30. Describe an optical device that you would like to see invented in your lifetime. Include a labelled sketch of a possible design as part of your answer. c

After Writing

Thinking Literacy

Reflect and Evaluate

This chapter offers several opportunities for you to analyze issues or situations. Using one of your written pieces, explain to a partner what you have learned about the importance of asking an initial question, providing background information, and making an evaluation of the issue or situation.

Unit Task Link

In your unit task, you will design and build a shade for streetlights that will reduce or eliminate light pollution in the night sky. Will your design reduce light pollution but still illuminate a wide area of ground? Make a list of tools and materials that you will need to build your streetlight.

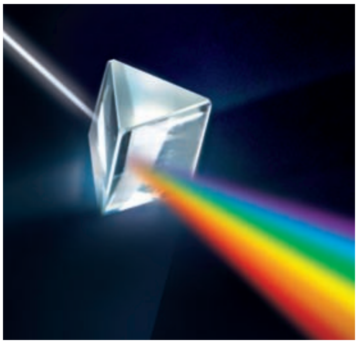
UNIT D Summary

KEY CONCEPTS	CHAPTER SUMMARY
10	**Light is part of the electromagnetic spectrum and travels in waves.**
• Electromagnetic spectrum • Wave model of light • Sources of light • Ray model of light • Interactions of light with matter	• Several properties of light can be explained using the wave model. • White light can be separated into all the colours of the rainbow, with each colour having a different wavelength. • The electromagnetic spectrum is split into various parts, some with longer wavelengths than visible light and some shorter than visible light. • Light can be produced in many ways. • White light may be treated as a combination of three different primary colours that can be combined or separated. • The ray model describes how light interacts with matter. • Light can be absorbed, reflected, or refracted as it goes from one medium to another.
11	**Ray diagrams model the behaviour of light in mirrors and lenses.**
• Law of reflection • $M = \frac{h_i}{h_o}$ and $M = \frac{d_i}{d_o}$ • $n = \frac{c}{v}$ • $n_1 \sin\theta_1 = n_2 \sin\theta_2$ • $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$	• The law of reflection states that the angle of incidence equals the angle of reflection as measured from the normal. • Concave mirrors can be used for magnification. Magnification is the measure of how much larger or smaller an image is compared with the object itself. • The speed of light is highest in a vacuum and lower in different media. • Refraction is the bending of light as it crosses the boundary between two media. • Snell's law relates the angles of incidence and refraction of a light ray to the indices of refraction of the two media. • Total internal reflection occurs when light reflects completely off the wall within a denser medium rather than passing through into a less dense medium. • Images can be virtual or real depending on how they were reflected or refracted by mirrors or lenses. • The thin lens equation relates the distance of the object from the lens, the distance of the image from the lens, and the focal length of the lens.
12	**Optical devices help us see farther and more clearly than we can with unaided eyes.**
• Human vision • Correcting human vision problems • Use of cameras • Microscopes and telescopes • Laser light • Photonics	• Human vision can be corrected using lenses. • Laser vision correction involves reshaping the cornea and has both advantages and disadvantages. • Widespread use of cameras has raised concerns over privacy. • Microscopes and telescopes make use of lenses and mirrors. • Photonics, the technology of using photons of light, has many applications that benefit society.

VOCABULARY

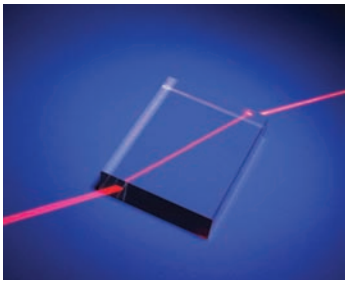
KEY VISUALS

- additive colour theory (p. 387)
- amplitude (p. 382)
- bioluminescence (p. 392)
- chemiluminescence (p. 395)
- crest (p. 382)
- diffuse reflection (p. 406)
- electric discharge (p. 396)
- electroluminescence (p. 397)
- electromagnetic radiation (p. 385)
- electromagnetic spectrum (p. 385)
- fluorescent (p. 394)
- frequency (p. 382)
- gamma rays (p. 385)
- incandescent (p. 394)
- infrared waves (p. 384)
- light-emitting diode (p. 397)
- liquid crystal (p. 398)
- liquid crystal display (p. 398)
- microwaves (p. 384)
- model (p. 386)
- opaque (p. 404)
- organic light-emitting display (p. 397)
- penumbra (p. 405)
- phosphor (p. 394)
- phosphorescence (p. 395)
- plasma display (p. 398)
- prism (p. 386)
- property (p. 386)
- radio waves (p. 384)
- ray model of light (p. 404)
- reflect (p. 388)
- regular reflection (p. 406)
- rest position (p. 382)
- subtractive colour theory (p. 388)
- translucent (p. 404)
- transparent (p. 404)
- triboluminescence (p. 396)
- trough (p. 382)
- ultraviolet rays (p. 385)
- umbra (p. 405)
- visible spectrum (p. 386)
- wave (p. 382)
- wave model of light (p. 386)
- wavelength (p. 382)
- X-rays (p. 385)



The visible spectrum of white light

- angle of incidence (p. 417)
- angle of reflection (p. 417)
- axis of symmetry (p. 450)
- concave lens (p. 451)
- concave mirror (p. 421)
- converging lens (p. 452)
- converging mirror (p. 421)
- convex lens (p. 452)
- convex mirror (p. 421)
- dispersion (p. 440)
- diverging lens (p. 451)
- diverging mirror (p. 426)
- focal length (p. 420)
- focal point (p. 420)
- geometric optics (p. 417)
- image (p. 418)
- incident ray (p. 418)
- index of refraction (p. 437)
- law of reflection (p. 418)
- lens (p. 450)
- magnification (p. 423)
- medium (p. 436)
- mirage (p. 443)
- normal (p. 418)
- optical device (p. 418)
- optical fibre (p. 418)
- plane mirror (p. 419)
- real image (p. 420)
- refraction (p. 436)
- Snell's law (p. 441)
- solar oven (p. 423)
- thin lens (p. 452)
- thin lens equation (p. 454)
- total internal reflection (p. 442)
- vertex (p. 420)
- virtual image (p. 419)



Light refracts as it moves from one medium into another.

- aperture (p. 484)
- astigmatism (p. 474)
- binoculars (p. 489)
- blind spot (p. 472)
- camera (p. 484)
- colour blindness (p. 477)
- colour vision deficiency (p. 477)
- compound microscope (p. 487)
- cone cells (p. 472)
- cornea (p. 470)
- diaphragm (p. 484)
- far-sighted (p. 473)
- iris (p. 470)
- laser (p. 490)
- near-sighted (p. 474)
- optic nerve (p. 472)
- optometrist (p. 469)
- ophthalmologist (p. 469)
- photons (p. 491)
- photonics (p. 491)
- photoreceptors (p. 472)
- pixels (p. 485)
- pupil (p. 470)
- reflecting telescope (p. 489)
- refracting telescope (p. 488)
- retina (p. 471)
- rod cells (p. 472)
- shutter (p. 484)
- telephoto lens (p. 485)
- telescope (p. 488)
- wide-angle lens (p. 485)

Visual recording devices are used around the world.

How Much Light Is Too Much Light?

(a)

(b)

Figure 12.45 The night sky from an Ontario town (a) during a blackout and (b) with light pollution

Getting Started

When the power went out in Ontario in August 2003, many people looked at the night sky in amazement. They had not realized how many stars were visible from their communities and cities because the beauty of the night sky was usually hidden behind a haze of light.

The yellowish dome of light that you may see over a distant city at night is caused by light pollution. Light pollution is a term given to unwanted, unnecessary, and wasteful light.

Your Goal

An astronomical observatory is to be built near your city. In order for the observatory to be effective, the light pollution in the city must be drastically reduced. Your goal is to design a shade for streetlights. The streetlights must continue to illuminate the streets and walkways, but there should be as little wasted light energy as possible distributed to the sides or above the streetlights.

Criteria for Success

- Your shade must illuminate surfaces below the light but allow little or no light to show on the sides and above the shade.
- Your shade will be evaluated by the amount of light that illuminates the ground and the amount of light that pollutes the sky. Your teacher will use a light meter to measure the light intensity produced at different heights above and below the streetlight.
- You will need to be prepared to discuss with the class the design of your shade and how it accomplishes its goals.

What You Need to Know

Many cities and communities have a problem with light pollution caused by parking lot lights, lights in commercial buildings and sports facilities, and streetlights.

The function of streetlights is to illuminate the streets, but many designs of lights also distribute light up and to the side. Some streetlights waste as much as 25 percent of their energy by lighting up the sky as well as illuminating the ground. The glare from inefficient lighting can be hazardous to vehicle drivers on the road and to airplane pilots flying overhead. The cost of all that wasted energy is passed on to the taxpayers and ultimately to the environment.

What You Need

- heat-resistant materials
- light bulb and socket as set up by your teacher
- light meter

CAUTION: Do not shine bright light into anyone's eyes. Incandescent light sources can become very hot. Do not touch the bulbs or block air flow around the bulbs. Heat resistant materials should be used around the bulb. No material should actually touch the bulb or the connections on the socket.

Procedure

1. Meet with your group members to discuss the role each team member will play in researching, designing, and building the shade. As well as preventing upward illumination, consider how wide a patch of ground is illuminated. A broad illumination is better than a spotlight since it means streetlights may be placed farther apart so fewer are needed and more energy is saved.
2. ***ScienceSource*** Research how streetlights are designed and how they contribute to light pollution for astronomers. Also research new streetlight designs that reduce or eliminate the upward illumination of streetlights. List a bibliography of all websites and books consulted to research the project.
3. Work together to decide what materials are needed. Create a drawing or detailed plan of how it will be constructed, and include a materials list. Before proceeding with the construction of the shade, show these plans to your teacher for feedback and approval.
4. Your teacher will set up one light fixture and bulb for the class. This will enable all projects to be tested in the same conditions. Your teacher must approve your design before you can test it.
5. Place your shade on the light. Use the light meter to test the shade. Measure the intensity of the light in three places:
   (a) on the ground directly underneath the light. Also measure how wide a path of ground is illuminated.
   (b) at a height of 1.0 m, 30 cm to the left or right of the light. This value should be much less than at the ground.
   (c) at a height of 1.5 m, 30 cm to the left or right of the light. This value should be as close to zero as possible.

   Your teacher will use the same method to check for the intensity of the light provided by your shade.
6. If necessary, make whatever modifications necessary to improve your shade based on the results of step 5. Be sure to test the shade in exactly the same conditions as the first test.
7. When you are satisfied with the performance of the shade, submit it to your teacher for testing. Prepare a summary of the features the shade has to make it effective. Be ready to discuss your design with the teacher/class.

Assessing Your Work

8. What do you think were the design features that best enabled the shade to reduce light pollution?
9. Did the features that helped to reduce light pollution also reduce the light available at ground level? If so, what modifications could you incorporate into your shade that would increase the light available at ground level without producing light pollution?
10. What design features did you see in shades produced by other groups that your shade did not have? Assess the effectiveness of these other designs.
11. Identify the issues that might arise if a city were to implement a shade similar to the one that you designed to eliminate light pollution.

UNIT D Review

ACHIEVEMENT CHART CATEGORIES

(k) Knowledge and understanding (t) Thinking and investigation
(c) Communication (a) Application

Key Terms Review

1. Create a mind map using the following terms. You may add more terms if you wish. (c)
    - angle of incidence
    - angle of reflection
    - angle of refraction
    - camera
    - concave mirror
    - converging lens
    - convex mirror
    - diverging lens
    - focal point
    - luminescence
    - magnification
    - microscope
    - mirage
    - telescope
    - virtual image

2. In a short paragraph, describe properties of light. You may wish to use some of the terms from question 1. (c)

10 Light is part of the electromagnetic spectrum and travels in waves.

3. (a) Draw a sketch of the electromagnetic spectrum. (k)

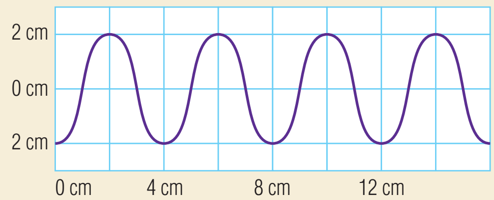
   (b) Label the different types of electromagnetic radiation. (k)

4. What is the difference between electromagnetic radiation and the electromagnetic spectrum? (k)

5. (a) What is the amplitude of the wave below? (k)

   (b) What is the wavelength of the wave below? (k)

   (c) Copy the wave into your notebook and label amplitude, wavelength, crest, trough, and resting position. (k)



Question 5

6. What is the relationship between wavelength and frequency? (k)

7. List the colours of the visible spectrum, from lowest to highest energy. (k)

8. (a) What are the three primary colours of light? (k)

   (b) What are the three secondary colours of light? (k)

   (c) Describe how each secondary colour of light is produced. (k)

9. In terms of subtractive colour theory, explain why a darker coloured object will heat up faster than a lighter coloured object. (k)

10. What colour of light would you observe if you combined equally bright lights of the three primary colours? (k)

11. (a) Name seven different sources of light. (k)

    (b) Give an example of each source. (k)

12. State how fluorescence and phosphorescence are:

    (a) similar (k)

    (b) different (k)

13. What assumption does the ray model of light make about how light travels? Ⓚ

14. (a) List three terms that describe how light interacts with various materials. Ⓚ
(b) Give an example of each interaction. Ⓚ

15. Is light transmitted through the frosted glass shown below? Explain. Ⓚ

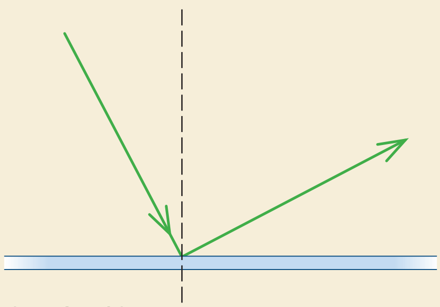
Question 15

16. How many primary colours does an LCD or plasma display need to produce all the colours of the rainbow? Ⓚ

17. Use the ray model of light to describe the difference between penumbra and umbra. Ⓚ

11 Ray diagrams model the behaviour of light in mirrors and lenses.

18. (a) State the law of reflection. Ⓚ
(b) Does the reflected ray in the illustration below obey the law of reflection? Explain why it does or does not. Ⓚ



Question 18

19. How is a virtual image different from a real image? Ⓚ

20. Draw a ray diagram to show why your image is reversed in a plane mirror. Ⓚ

21. How is the focal point of a mirror different from the vertex? Ⓚ

22. (a) Draw a ray diagram of an object $0.75f$ from a concave mirror. Ⓚ
(b) Draw a ray diagram of an object $0.75f$ from a convex mirror. Ⓚ

23. What are two versions of the magnification formula? Ⓚ

24. State two uses for:
(a) a concave mirror Ⓚ
(b) a convex mirror Ⓚ

25. What is the definition of refraction? Ⓚ

26. Which substance refracts light more, water or glass? Explain why. Ⓚ

27. What is the speed of light? Ⓚ

28. (a) What is the definition of index of refraction? Ⓚ
(b) What is the formula for calculating the index of refraction of a material? Ⓚ

29. What is a common example of dispersion? Ⓚ

30. State the quantities that are related by Snell's law. Ⓚ

31. (a) Define critical angle. Ⓚ
(b) How can the value of the critical angle be measured? Ⓚ

32. How can you tell the difference between regular and diffuse reflection? Ⓚ

33. Which will be larger: the critical angle at an air-glass interface or the critical angle at a water-glass interface? Explain. Ⓚ

34. How does a mirage form? Ⓚ

UNIT D Review (continued)

35. (a) Draw a ray diagram for an object 0.75f from a converging lens.
    (b) Draw a ray diagram for an object 1.25f from a converging lens.

36. State the thin lens equation.

37. In the thin lens formula for a convex lens, state when the image distance is:
    (a) positive
    (b) negative

38. Explain the appearance of the reflection of the building in the photograph below.

Question 38

12 Optical devices help us see farther and more clearly than we can with unaided eyes.

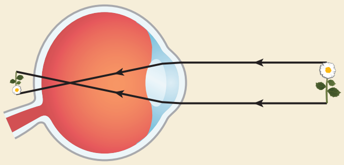
39. List two parts of the eye that can refract light.

40. What structure controls the amount of light that enters the eye?

41. What features of an image are primarily collected by:
    (a) rods
    (b) cones

42. State the cause of:
    (a) far-sightedness
    (b) near-sightedness

43. (a) What type of vision problem does the eye below have?
    (b) Copy the diagram into your notebook. Add a correcting lens to your diagram, and show how the lens bends the light rays to focus the image on the retina.



Question 43

44. Laser eye surgery can be used in some cases to correct far-sightedness and near-sightedness. What are three other conditions of the eye that can be treated with laser surgery?

45. Compare the features of an image from a telephoto lens and an image from a wide-angle lens.

46. Use a labelled ray diagram to show how an image is produced in a microscope.

47. (a) What type of telescope is the preferred type for large astronomical observatories?
    (b) Why is it preferable?

48. How is laser light different from ordinary light?

49. How does photonics model properties of light?

Connect Your Understanding

50. Draw a ray diagram and write a short explanation to show why it is sometimes difficult to reach a coin that is underwater in a pond.

51. A flashlight does not lose power as you walk away from it, but as you get farther and farther, it appears to be less and less bright. Explain why. *a*

52. Describe three situations where sunlight is seen as the visible spectrum. *a*

53. You are standing outside in the dark, waiting for a fireworks display, and an extremely bright flash goes off right above you. Describe the behaviour of your pupils before, during, and after the flash. *t*

54. When part of the Moon passes through Earth's umbra, the result is a partial lunar eclipse, as shown below. What happens when the entire Moon passes through Earth's umbra? Draw a labelled diagram as part of your answer. *t*

Question 54

55. If you wish to take a picture of faint stars in the night sky, how should you adjust your camera? *t*

56. Describe how night vision goggles enhance human vision. *c*

57. Many grocery stores carry "reading glasses" that you can buy to help you read small print. What kind of lenses do you think these glasses use? Explain. *a*

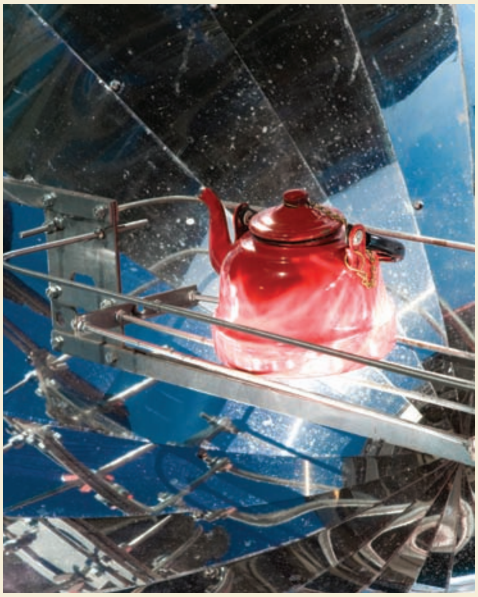
58. Explain why you agree or disagree with the following statements. For any you disagree with, provide the correct statement. *t*
    (a) The normal is drawn at a 90° angle to the mirror or lens.
    (b) When light is reflected from a curved mirror, the angle of incidence is twice the angle of reflection.
    (c) If you want to see farther into space, build a telescope with a bigger convex mirror.
    (d) The two main lenses of the microscope are the eyepiece and the objective lens.

59. Why is it important that a optical fibre not have any scratches on its surface? *c*

60. When purchasing a diamond, people often use a microscope to look for tiny imperfections within the diamond. In which case would the imperfections be more visible, with the diamond immersed in water or in air? Why? *t*

61. A hiker sees a mirage of trees in the sky. Draw a diagram to show how this is possible. Label the different air temperature regions. *c*

62. Describe what is happening in the following photograph. (a)



Question 62

Skill Practice

63. A movie projector magnifies an image on 70.0-mm film to fill a screen 2.40×10^4 mm wide. What is the magnification provided by the projector? (k)

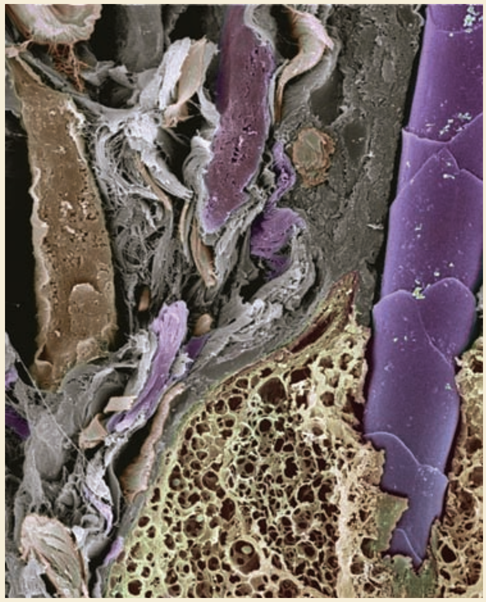
64. A concave lens produces a virtual image of a flower petal 2.00 cm from the lens. Determine the magnification of the lens if the petal is 8.30 cm from the lens. (k)

65. When light passes through sodium gas at –272°C, it slows to 16.7 m/s. What is the index of refraction of sodium gas at this temperature? (k)

66. Light travels through a salt crystal that has a refractive index of 1.52. What is the speed of light in the crystal? (k)

67. Titan is a moon of Saturn that has liquid methane in the atmosphere. Liquid methane has an index of refraction of 1.29. If a beam of light from the Sun approaches the atmosphere of Titan at an angle of 36.0°, what is its angle of refraction? (k)

68. A human hair follicle like the one in the photo below appears to be 5.5×10^{-3} m in width when viewed by a lens that magnifies 50 times. What is the actual width of the hair follicle? (k)



Question 68

69. A lens produces a larger, upright, virtual image that is 12.25 cm from the lens. The object is located 5.10 cm away. What is the focal length of the lens? (k)

70. A convex lens has a focal length of 1.80 cm. If it is held 3.0 cm from an object, how far from the lens is the image formed? (k)

71. A far-sighted person wearing a pair of glasses looks at the soup display in the grocery store. If the convex lenses in the glasses have a focal length of 2.40 m and form a virtual image 2.60 m from the lenses, how far away is the display? (k)

72. Follow these steps to find the relationship between the focal length of a spherical concave mirror and its radius of curvature:
- Draw a concave mirror with a radius of at least 20 cm.
- Mark the centre of the mirror on the principal axis.
- Draw a ray parallel to the principal axis, no more than 3 cm away from the axis.
- Draw a dotted line from the point of incidence to the centre of the mirror. This is the normal.
- Use the law of reflection to draw the reflected ray.
- Locate where the ray crosses the principal axis. This is the focal point.

(a) How do you know the dotted line is the normal?

(b) How can you be sure that you have found the focal point?

(c) Compare the radius and the focal length. Hypothesize their relationship.

(d) Describe how you might verify this relationship. t

Revisit the Big Ideas and Fundamental Concepts

73. (a) Describe the differences between refraction and reflection as a way to change the direction of a light ray. c

(b) Describe how our understanding of these principles benefits society. c

74. How have various optical technologies changed human perceptions of the natural world? a

75. How have optical technologies such as cellphone cameras and security cameras changed human behaviour? t

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76. Describe some ways that optical devices have extended human capabilities and reduced the impact of disease, wear and tear, and trauma on the human eye. c

77. What are three different ways that human health has been affected by optical instruments? c

78. How have optical fibres enhanced our ability to communicate information? t

79. (a) Describe an example of when you think digital manipulation of an image is a good idea. c

(b) Describe an example of when you think digital manipulation should not be allowed. c

Reflection

80. What can you explain about light and the way it interacts with matter that you were not able to before reading this unit? c

81. Explain why it is important for you to understand properties of light and optics in your daily life. c

82. (a) Choose an optical device that you think has affected your life the most. c

(b) Explain how it has contributed to your life. c

83. What ideas in this unit are you are interested in learning more about? c