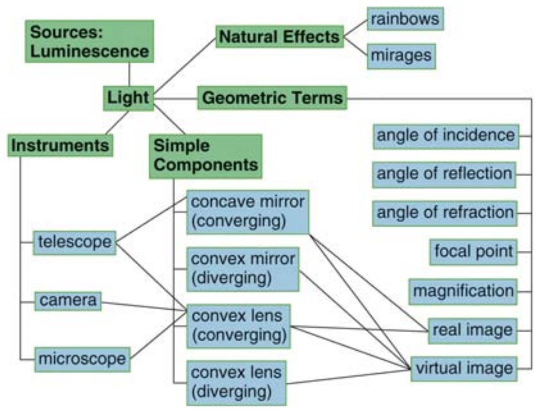
Pages 504–505

D Unit Review — ANSWERS TO QUESTIONS

Key Terms Review

1.

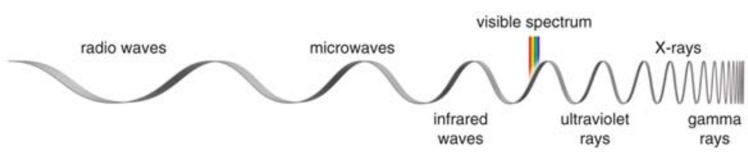


2. Students' answers will vary but should include discussion of most of these concepts:
- wave model, wavelength, frequency, colour
- sources, moving charges, atomic and molecular processes
- ray model, straight lines, shadows, speed
- reflection, regular or diffuse, law of reflection
- transmission, regular or diffuse; absorption
- refraction, dispersion, index of refraction, Snell's Law, total internal reflection

Key Concept Review

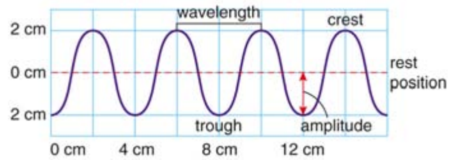
10

3. (a) and (b)



4. The electromagnetic spectrum is composed of many varieties of electromagnetic radiation.

5. (a) 2 cm
(b) 4 cm
(c)



6. For a wave travelling at a fixed speed, the wavelength gets shorter as the frequency gets higher. The formula is $v = f \times \lambda$.
7. The visible colours are red, orange, yellow, green, blue, and violet.
8. (a) The primary colours of light are red, green, and blue.
(b) The secondary colours of light are yellow, cyan, and magenta.
(c) Yellow light is a mixture of red and green light. Cyan light is a mixture of green and blue light. Magenta light is a mixture of blue and red light.
9. A dark object reflects very little light, so it absorbs a lot. The absorbed light is transformed into heat and the object warms up quickly. By contrast, a bright object reflects a lot of light and absorbs very little—not much light is transformed into heat and the object warms more slowly.
10. Combining red, green, and blue light produces a colour we perceive as white.
11.
- Incandescence (from heat): ordinary light bulb
- Fluorescence (phosphor absorbs UV and emits visible light): fluorescent paint
- Phosphorescence (phosphor absorbs UV and emits visible light over time): watch dial
- Chemiluminescence (from a chemical reaction): glow stick
- Triboluminescence (from friction): Ute ceremonial rattles
- Electric discharge (electric spark excites a gas): neon lamp
- Electroluminescence (from electric current in a semiconductor): LED

12. (a) In both fluorescence and phosphorescence, ultraviolet radiation excites a phosphor, which then emits visible light.
(b) In fluorescence, the ultraviolet light comes from a gas that has been excited by an electric discharge. The production of visible light stops as soon as the electric discharge stops. In phosphorescence, the ultraviolet light comes from sunlight (or an artificial source) and the phosphor emits visible light for a reasonably long time after the incoming light is removed.
13. The ray model of light assumes that light travels in straight lines.

14. Light may be reflected; for example, from the surface of water.
Light may be absorbed; for example, by black asphalt.
Light may be transmitted; for example, through a pane of glass.

15. Light is transmitted to some extent through the panes of glass. There is no clear image visible, so the transmission is diffuse. In addition, only red and green light pass through the yellow panes, only green and blue light pass through the cyan panes, and only blue and red light pass through the magenta panes.

16. The three additive primaries (red, green, and blue) can be combined in various amounts to make colours similar to all of the spectral colours.

17. Think about an object, a screen, and a reasonably large light source. There are three possibilities for lighting a point on the screen: a point may receive light from all parts of the light source, from some parts of the light source, or from no parts of the light source. The first point will appear bright. The second point will be in partial shadow (penumbra). The last point will be in total shadow (umbra).

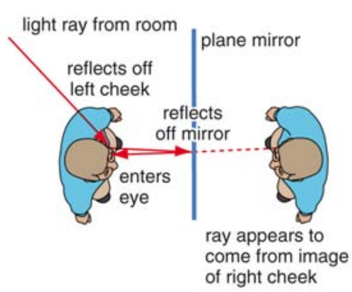
11

18. (a) The angle of reflection is the same as the angle of incidence, where both angles are measured from the normal to the reflecting surface.

(b) The angle of reflection appears to be larger than the angle of incidence. The law of reflection is not being followed.

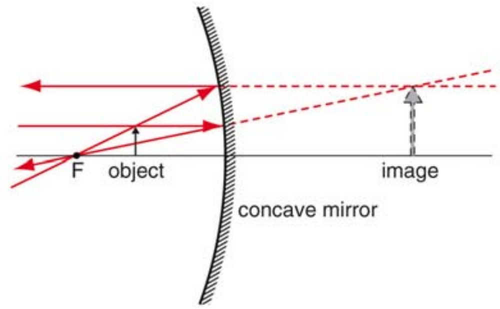
19. For a real image, light rays come together and focus. You can capture this image on a piece of paper. For a virtual image, light rays diverge as they enter your eye. They appear to have come from a focussed image but you can't get an image on a piece of paper.

20.

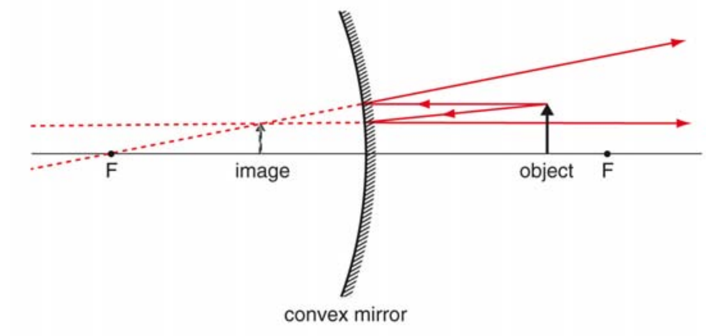


21. Rays of light parallel to the principal axis of a mirror reflect back through (or as if they had come from) a point called the principal focus. The vertex of a mirror is the point on the mirror where the principal axis touches the mirror.

22. (a) Students may also draw the following diagram using the guidelines for drawing ray diagrams on p. 429 of the student book. Go to ScienceSource.ca for a diagram done using those guidelines.



(b)



23. Magnification relates the image height to the object height:

$$M = \frac{h_i}{h_o}$$

Equivalently, for a single mirror or lens, it relates the image distance to the object distance: $M = \frac{d_i}{d_o}$

24. (a) Concave mirrors are used as shaving mirrors and in telescopes.
(b) Convex mirrors are used for store security and as passenger-side car mirrors.

25. Refraction is the bending of light as it crosses the boundary between materials in which light travels at different speeds.

26. The index of refraction of water is lower than that of glass. So, light entering water from air will be refracted less than light entering glass from air (with the same angle of incidence).

27. The speed of light is the speed of propagation of electromagnetic waves. In a vacuum, all electromagnetic waves travel at 3.0×10^8 m/s .

28. (a) The index of refraction of a material is a comparison of the speed of light in a vacuum with the speed of light in the material. It is also called the optical density of the material. It determines how much refraction occurs when light crosses into the material.

(b) $n = \frac{c}{v}$

29. An example of dispersion is the way a prism or watch crystal splits white light into its spectral colours.

30. Snell's law relates four quantities: angle of incidence in a first medium, the index of refraction of this medium, the angle of refraction in a second medium, and the index of refraction of this medium.

31. (a) When a ray of light strikes the interface between an optically more dense material and an optically less dense material, the refracted ray (if it exists) bends away from the normal. The angle of incidence that makes the angle of refraction 90° is called the critical angle.

(b) Aim an incident ray at the surface between the two materials. Increase the angle of incidence until there is only total internal reflection. The angle where refraction stops and total internal reflection begins is the critical angle.

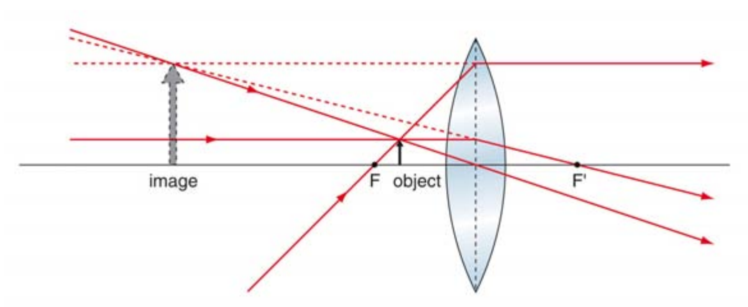
32. In regular reflection there is a clear image; in diffuse reflection there is no image or the image is fuzzy.

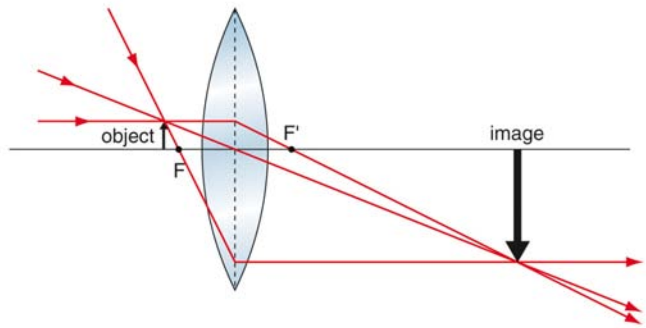
33. The indices of refraction of glass and air differ more than the indices of refraction of glass and water. This means that light moving from glass to air refracts more than light moving from glass to water. So, total internal reflection happens for smaller incident angles for a glass-to-air interface. The critical angle for glass to air is smaller than for glass to water.

34. A mirage forms when layers of air have different temperatures and different indices of refraction. A common mirage involves an image of the sky on the road or ground. Another type of mirage gives an image of distant objects in the sky. Both types involve total internal reflection.

Pages 506–507

35.





36. The thin lens formula is $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$, where f is the focal length, d_o is the object distance, and d_i is the image distance.

37. (a) The image distance is positive for a real image—the image is on the opposite side of the lens from the object and is inverted.

(b) The image distance is negative for a virtual image—the image is on the same side of the lens as the object and is upright.

38. The panes of glass on the building are not flat. Wherever the image of the opposite building is compressed, the pane is convex. Wherever the image of the opposite building is expanded, the pane is concave.

12

39. The cornea and the lens refract light.

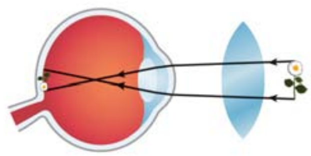
40. The iris opens and closes to adjust the size of the pupil, which is the opening through which light enters the eye.

41. (a) Rod cells specialize in detecting motion and collecting light in dim conditions.

(b) Cone cells specialize in detecting red, green, or blue light under bright conditions.

42. (a) In far-sightedness, the eye focusses the image of a close object behind the retina.
(b) In near-sightedness, the eye focusses the image of a far object in front of the retina.

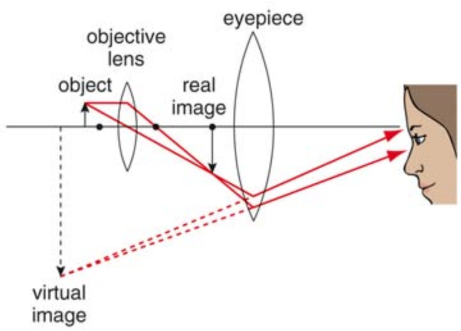
43. (a) The image falls into focus behind the eye. This is far-sightedness.
(b)



44. Laser surgery is used to correct astigmatism, re-attach retinas, and correct the some side effects of cataract removal.

45. Telephoto images show a very narrow field of view but give good detail of distant objects. Wide-angle images show a broad field of view but little detail of distant objects. Wide-angle lenses can also be used for close-up pictures of flowers—these images have good detail at a given distance but poor depth of focus.

46.



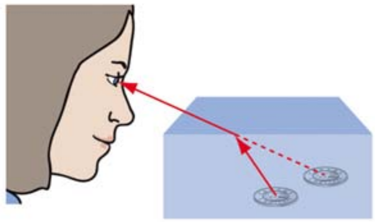
47. (a) Astronomers prefer reflecting telescopes.
(b) It is much easier to make a high quality large mirror than to make a high quality large lens. In addition, a mirror is much lighter than a comparable lens.

48. Laser light is all of a single wavelength with the waves oscillating together (in phase). The beam is extremely well collimated and, as a result, does not spread out very quickly.

49. The photon model of light treats light as a stream of very small particles or bundles of energy called photons. The photons move in straight lines and interact with atoms and molecules on a one-on-one basis.

Connect Your Understanding

50.



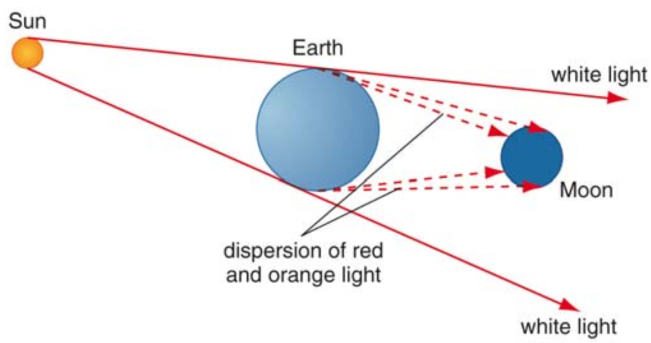
When you look at a coin under water, a light ray comes from the coin, refracts at the water surface, and goes into your eye. Your brain tells you to follow this last ray backwards to locate the coin—but the coin isn't there; it is deeper.

51. The flashlight has constant power—it gives off the same amount of light each second. However, the beam of light spreads out as it goes farther out from the flashlight. Your eye has a fixed size: it catches a lot of light from a narrow beam when you are close but only catches a bit of light from a broad beam when you are far away. You interpret this smaller amount of light as being dimmer.

52. You can see sunlight as a visible spectrum in a rainbow, refracting through a crystal, or reflecting off of a soap bubble.

53. Before the flash, your pupils would be reasonably wide open to help you see in dark conditions. Right after the flash, the pupils would close tightly to protect your eyes. Over the next while, the pupils would slowly dilate again to allow you see in the dark.

54.



When the Moon is completely within the umbra of Earth, there will be no bright white sunlit parts. The Moon will not look completely black because Earth's atmosphere acts like a dispersive lens and refracts some light from the Sun around to the Moon. It is the red part of the spectrum that is most strongly refracted making the Moon look orange.

55. To capture faint distant stars, the camera needs to be focussed at infinity with the largest possible aperture and a long exposure.

56. The small amount of light entering the goggles causes an image intensifier to release streams of particles. These strike a phosphor-coated screen and transfer their energy to the phosphor, which then emits visible light forming a strong image.

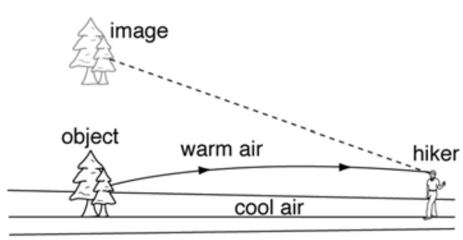
57. If you have trouble reading the small print, you are far-sighted. You need converging (convex) lenses to focus strongly diverging light properly on your retinas.

58. (a) Agree
(b) Disagree; the angle of reflection is always equal to the angle of incidence.
(c) Disagree; reflecting telescopes use concave mirrors.
(d) Agree

59. Total internal reflection works because light strikes the surface of the tube or cable at an angle larger than the critical angle. If there are scratches, the light may hit a scratch at an angle that allows it to refract out of the tube or cable, and so the signal gets lost.

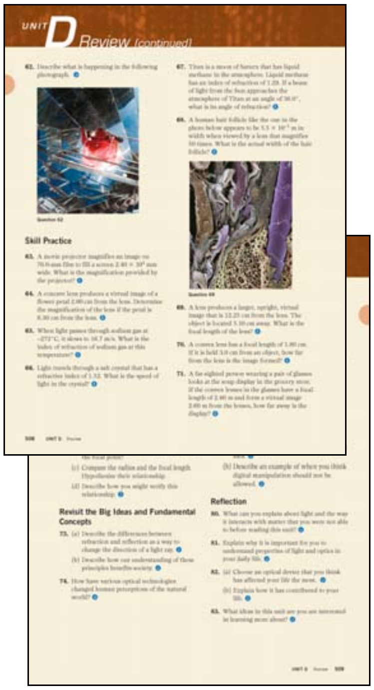
60. To see inside the diamond, you need light to be coming out of the diamond and into your eye. Since water has a higher index of refraction than air, light leaving diamond going into water is bent less than if going into air. Light striking a diamond–air surface might be totally reflected. You should be able to examine a diamond better under water.

61.



62. Sunlight is reflected from the convex mirror under and around the kettle. The kettle is located near the focal point of the mirror and is heated by the converging rays of sunlight.

Pages 508–509



Skill Practice

63. ***Given***

Object height $h_o = 70.0$ mm

Image height $h_i = 2.40 \times 10^4$ mm

Required

Magnification M = ?

Analysis and Solution

The correct equation is $M = \dfrac{h_i}{h_o}$

Substitute the values and their units and solve the problem.

$$
\begin{aligned}
M &= \frac{h_i}{h_o} \\
&= \frac{2.40 \times 10^4 \text{ mm}}{70.0 \text{ mm}} \\
&= 3.4286 \times 10^2
\end{aligned}
$$

Paraphrase

The magnification of the microscope is 343 times.

64. ***Given***

Object distance $d_o = 8.30$ cm

Image distance $d_i = 2.00$ cm

Required

Magnification M = ?

Analysis and Solution

The correct equation is $M = \dfrac{d_i}{d_o}$

Substitute the values and their units and solve the problem.

$$
\begin{aligned}
M &= \frac{d_i}{d_o} \\
&= \frac{2.00 \text{ cm}}{8.30 \text{ cm}} \\
&= 0.2410
\end{aligned}
$$

Paraphrase

The magnification of the concave mirror is about 0.241 times.

65. *Given*

Speed of light in sodium gas $v = 16.7\ \text{m/s}$

Speed of light in vacuum $c = 3.00 \times 10^8\ \text{m/s}$

Required

Index of refraction of sodium gas n = ?

Analysis and Solution

The correct equation is $n = \dfrac{c}{v}$

Substitute the values and their units and solve the problem.

$$\begin{aligned} n &= \frac{c}{v} \\ &= \frac{3.00 \times 10^8\ \text{m/s}}{16.7\ \text{m/s}} \\ &= 1.7964 \times 10^7 \end{aligned}$$

Paraphrase

The index of refraction of sodium gas is about 1.80×10^7.

66. *Given*

Index of refraction of salt crystal n = 1.52

Speed of light in vacuum $c = 3.00 \times 10^8\ \text{m/s}$

Required

Speed of light in salt crystal v = ?

Analysis and Solution

The correct equation is $n = \dfrac{c}{v}$

Rearrange it to solve for the variable needed: $v = \dfrac{c}{n}$

Substitute the values and their units and solve the problem.

$$\begin{aligned} v &= \frac{c}{n} \\ &= \frac{3.00 \times 10^8\ \text{m/s}}{1.52} \\ &= 1.9737 \times 10^8\ \text{m/s} \end{aligned}$$

Paraphrase

The speed of light in salt crystal is about $1.97 \times 10^8\ \text{m/s}$.

67. Identifying vacuum as medium 1 and liquid methane as medium 2:

Given

Index of refraction of vacuum $n_1 = 1.00$

Index of refraction of liquid methane $n_2 = 1.29$

Angle of incidence $\theta_1 = 36.0°$

Required

Angle of refraction $\theta_2 = ?$

Analysis and Solution

The correct equation is $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Rearrange it to solve for the variable needed: $\sin\theta_2 = \dfrac{n_1 \sin\theta_1}{n_2}$

Substitute the values and their units and solve the problem.

$$\begin{aligned}\sin\theta_2 &= \frac{n_1 \sin\theta_1}{n_2} \\ &= \frac{1.00 \times \sin(36.0°)}{1.29} \\ &= 0.4556\end{aligned}$$

Take the inverse sine of both sides: $\theta_2 = 27.11°$

Paraphrase

The angle of refraction is about 27.1°.

68. ***Given***

Image height $h_i = 5.5 \times 10^{-3}$ m

Magnification $M = 50$

Required

Object height $h_o = ?$

Analysis and Solution

The correct equation is $M = \dfrac{h_i}{h_o}$

Rearrange it to solve for the variable needed: $h_o = \dfrac{h_i}{M}$

Substitute the values and their units and solve the problem.

$$\begin{aligned}h_o &= \frac{h_i}{M} \\ &= \frac{5.5 \times 10^{-3}\ \text{m}}{50} \\ &= 1.100 \times 10^{-4}\ \text{m}\end{aligned}$$

Paraphrase

The width of the follicle is about 1.1×10^{-4} m or 0.11 mm.

69. ***Given***

Distance of object from the lens $d_o = 5.10$ cm

Distance of virtual image from lens $d_i = -12.25$ cm

Required

Focal length of the lens f = ?

Analysis and Solution

The correct equation is $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

Substitute the values and their units, and solve the problem.

$$\begin{aligned}\frac{1}{f} &= \frac{1}{d_o} + \frac{1}{d_i} \\ &= \left(\frac{1}{5.10} + \frac{1}{-12.25}\right)\frac{1}{\text{cm}} \\ &= \frac{0.1144}{\text{cm}}\end{aligned}$$

Take the reciprocal of both sides: $f = 8.738$ cm

Paraphrase

The focal length is about 8.74 cm.

70. ***Given***

Distance of object from the lens $d_o = 3.0$ cm

Focal length of the lens $f = 1.8$ cm

Required

Distance of the image from lens $d_i = ?$

Analysis and Solution

The correct equation is $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

Rearrange the formula for $\frac{1}{d_i}$: $\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$

Substitute the values and their units, and solve the problem.

$$\begin{aligned}\frac{1}{d_i} &= \frac{1}{f} - \frac{1}{d_o} \\ &= \left(\frac{1}{1.8} - \frac{1}{3.0}\right)\frac{1}{\text{cm}} \\ &= \frac{0.2222}{\text{cm}}\end{aligned}$$

Take the reciprocal of both sides: $d_i = 4.500$ cm

Paraphrase

Since the image distance is positive, the image is real. It is located about 4.5 cm from the lens.

71. ***Given***

Distance of virtual image from the lens $d_i = -2.60$ m

Focal length of the lens $f = 2.40$ cm

Required

Distance of the object from lens $d_o = ?$

Analysis and Solution

The correct equation is $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

Rearrange the formula for $\frac{1}{d_o}$: $\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$

Substitute the values and their units, and solve the problem.

$$\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$$

$$= \left(\frac{1}{2.40} - \frac{1}{-2.60}\right)\frac{1}{\text{m}}$$

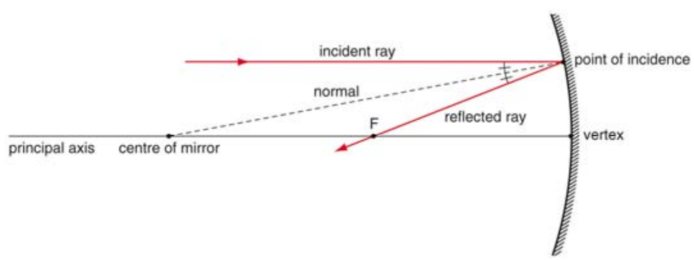
$$= \frac{0.8013}{\text{m}}$$

Take the reciprocal of both sides: $d_o = 1.248\,\text{m}$

Paraphrase

The shelf is about 1.25 m from the person's glasses.

72.



(a) Any line segment joining the centre of a circle to the circle itself (i.e. a radius) is perpendicular to the circle.

(b) Draw another line parallel to the principal axis and repeat the construction. The reflected ray should pass through the same point.

(c) The focal length is just a bit less than one-half of the radius of the circle. This suggests the relation $f = \frac{1}{2}r$.

(d) I could draw mirrors of various radii and repeat the construction, looking to see if the new focal length is one-half of the new radius. Experimentally, I could make mirrors of various radii from aluminum foil and then use a beam of light to find the focal points (and focal lengths); again, I would need to check whether the relation holds. Or, I could research the geometry of a circle and see if there is some useful result that allows me to try a formal geometric proof!

Revisit the Big Ideas and Fundamental Concepts

73. (a) Reflection redirects light back, more or less in the direction it came from. The law of reflection says the reflected angle on one side of the normal is the same as the incident angle on the other side of the normal. Refraction redirects light as it passes into or out of a material, more or less in the forward direction. Snell's law relates the angle of refraction on one side of the normal to the angle of incidence on the other side of the normal.

(b) Many optical devices use mirrors (reflection) and lenses (refraction). The devices are used in health science, for basic research, for communications and for navigation, all applications that benefit society.

74. Microscopes have allowed us to see organisms that are too small to see with the human eye. Telescopes have allowed us to see details of the Moon, Sun, planets, stars, and other astronomical objects that are too far away to see clearly.

75. Cellphone cameras and security cameras allow most public occurrences to be recorded, with or without the knowledge of those participating. In many circumstances this reduces criminal behaviour and increases people's sense of safety. In other situations, this invades privacy, causing ordinary people to be less spontaneous and celebrities to avoid previously normal activities such as walking a dog.

STSE Science, Technology, Society, and the Environment

76. Students' answers may vary but should include some of these points:

- corrective lenses have allowed people to see clearly close up and at a distance
- microscopes have permitted us to see at a very small scale revealing organisms that are responsible for disease
- telescopes have allowed us to see farther on Earth's surface for navigation and safety
- telescopes have allowed us to see into space and begin to understand the universe
- lasers are used to correct many visions difficulties and treat some eye diseases
- protective eyewear, ultraviolet filter coatings, and polarized lenses make it safer and easier to see when working and driving

77. Students' answers may vary but should include some of these points:

- fibre optics are a major component of various endoscopes used to examine and treat internal conditions with minimal trauma to surrounding tissues
- digital cameras are another important part of scoping technology
- laser surgery is used to correct many vision problems

78. Optical fibres are used in telephone cables to send many signals at the same time without loss of clarity.

79. (a) It is reasonable to use digital manipulation to improve the aesthetics of a picture, for example, to hide a telephone wire in an image of the sky.

(b) Digital manipulation should not be used to alter images and publish them where they can be used to mislead readers.

Reflection

Students' answers will vary but might be similar to the following:

80. Light travels like a wave and this explains why it reflects and refracts the way it does. I learned that different wavelengths of light have slightly different indices of refraction; this is why raindrops and prisms can separate white light into colours.

81. Many medical devices use mirrors, lenses, fibre optic cables, and digital cameras. It is important to understand how these work to make good decisions about diagnostic and treatment choices.

I need glasses to see properly when I ride my bike and I have found I have trouble with contact lenses. Understanding optics helps me understand the issues about corrective surgery.

82. I think the digital camera has affected me the most. I love taking and editing pictures and hope to make a career in media.

Binoculars have affected me the most. I have used them birding and looking at butterflies. Now I am interested in studying wildlife management.

83. I would like to learn about producing colour on electronic screens: What are the technologies being developed to replace plasma and LCD display? I want to learn more about why some materials make better reflectors than others: What determines how much light is reflected and how much is refracted?