Get Ready for Unit 4

Light and Geometric Optics

Answers for page 140

Multiple Choice

1. e

2. c

3. c

4. b

5. b

6. a

7. b

8. b

Answers for page 141

Written Answer

9. A natural source of light is one that emits light energy on its own, like the Sun. An artificial source of light is a source that either reflects light but does not emit light itself, or the source is a result of human manufacture. For example, we see the Moon because sunlight reflects off its surface and reaches our eyes.

10. When white light passes through a prism, it bends and separates into different colours.

11.

Light Source	Type (Natural or Artificial)
Sun	Natural
Lamp	Artificial
Aurora	Natural

12. Reflection of light is the phenomenon in which light strikes and bounces off a surface.

13. Refraction of light is the phenomenon in which light bends as it passes from one medium to another, at an angle.

14. Telescopes and microscopes use properties of light. Eyeglasses, binoculars, mirrors, periscopes, and contact lenses also use properties of light.

15. ƎƆIꞀOd

16. a. AF and CD, AB and ED, FE and BC **b.** Yes, all angles are the same: 120˜

Section 10.1 Review

Sources and Nature of Light

Answers for page 142

Multiple Choice

1. d

2. e

3. e

4. b

5. b

6. d

7. b

8. c

Answers for page 143x

Written Answer

9. For all light sources, atoms within the materials must absorb some form of energy. After absorbing energy, the atoms go into an excited state. To return to their natural state, they must emit energy. This energy is often in the form of light.

10. When electric current runs through the tiny tungsten wire of an incandescent light bulb, the wire gets very hot. The electric energy excites the tungsten atoms, and as the tungsten atoms return to their natural state they give off light. As a result, it glows brightly.

11. Part A is an electrode; part B is the electrical energy source; part C is the vacuum tube.

12. An electric discharge bulb has an electrode at each end (one electrode is shown as part A). A drop of sodium with a small amount of mercury are placed in the bulb. When most of the air is removed from the bulb, the sodium and mercury form a vapour in the bulb. An electric current passes through this vapour and excites the atoms. When the excited atoms release their energy, they emit light.

13. Luminescence is light that is generated without heating the object. The energy used to excite the atoms comes from a variety of sources. Three types of luminescence are phosphorescence, chemiluminescence, and bioluminescence.

14. A wavelength is the distance from one crest (or trough) of the wave to the next.

15. Electromagnetic waves are waves that can travel through a vacuum and do not need particles to travel. Their speed in a vacuum is 3.00×10^8 m/s. Electromagnetic waves are comprised of electric and magnetic fields.

16. Fluorescence is light emitted during exposure of the source to ultraviolet light. Phosphorescence is similar to fluorescence, except the excited atoms in a phosphorescent material retain the energy for several minutes or even a few hours. Therefore, phosphorescent materials glow long after they have absorbed ultraviolet light.

Section 10.2 Review

Properties of Light and Reflection

Answers for page 144

Multiple Choice

1. b

2. d

3. b

4. c

5. e

6. c

7. e

8. a

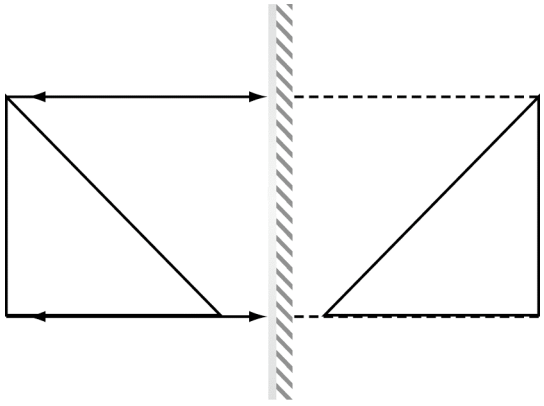
Answers for page 145

Written Answer

9. A medium is a substance through which light travels.

10. A ray is a straight line with an arrowhead that shows the direction in which light waves are travelling.

11.



12. Fermat's principle states that light follows the path that will take the least time. When light reflects from a surface and remains in one medium, its speed is constant. Therefore, the path that takes the least time is the shortest path. Fermat's principle leads to the laws of reflection.

13. The incident ray, the reflected ray, and the normal always lie on the same plane. The angle of reflection, $\square r$, is equal to the angle of incidence, $\square i$. $\square r = \square i$

14. Dotted lines are used to distinguish the image from the real object.

15. An image formed in a plane mirror is the same distance as the object to the mirror, it is upright, it is the same size as the object, and it is a virtual image.

16. First, the shape of the stealth aircraft (flat sections, sharp corners) ensures that most radar rays will not return to the radar antenna when they are reflected—they will go in other directions. Second, a radar wave penetrates the base of the paint and then reflects from one particle to another. The paint absorbs most of the energy of the radar wave further reducing the amount of radar waves that return to the radar.

Section 10.3 Review

Images in Concave Mirrors

Answers for page 146

Multiple Choice

1. b

2. c

3. d

4. e

5. a

6. c

7. a

8. b

Answers for page 147

9. d

10. c

11. e

12. e

13. e

14. b

15. d

16. b

Answers for page 148

Written Answer

17. A radar antenna is in the shape of a parabolic concave mirror.

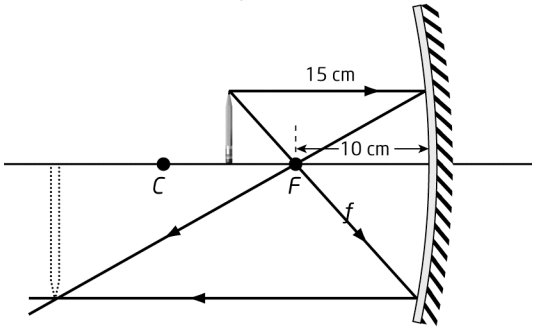
18. The radio wave generator and detector are located at the focal point.

19. $m = -35/10 = -3.5$; The magnification is –3.5.

20. The object should be placed at the solar oven's focal point.

21. The image will be real, inverted, smaller than the object, and between *C* and *F*.

22. $1/d_i = 1/f - 1/d_o$; $d_i = 30$ cm; the image distance is 30 cm.



23. The ray going along the principal axis goes through the horizontal centre of the concave mirror, so it is normal to the surface of the mirror. A ray hitting a surface along the normal reflects back on itself.

24. To produce a real image, the object should be beyond the focal point of the concave mirror. To produce a virtual image, the object should be placed between the focal point and the vertex.

Answers for page 149

25. As an object moves closer to a concave mirror, the image gets larger.

26. An object should be placed between the concave mirror and the focal point to produce an image that is larger than the object, virtual, and upright.

27. $f = 20$ cm; $d_o = 30$ cm; $d_i = ?$
$1/f = 1/d_o + 1/d_i$; $1/f - 1/d_o = 1/d_i$; $1/20 - 1/30 = 1/d_i$; $d_i = 60$ cm

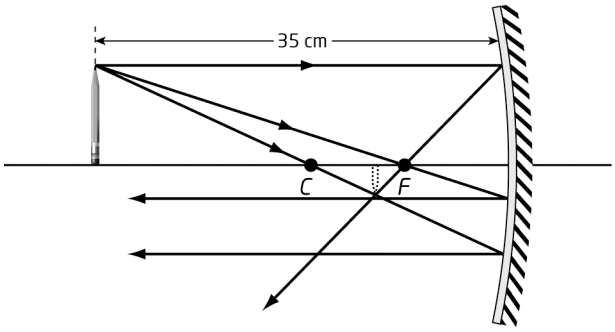
28. $m = -d_i/d_o = -60/30$; $m = -2$

29. $m = h_i/h_o$; $h_i = mh_o = -2(5)$; $h_i = -10$ cm

30. The value of d_i is positive, so the image is in front of the mirror and is real. The values of m and h_i are negative, so the image is inverted. The value of d_i is 60 cm. The centre of curvature is at 40 cm (2×20 cm), so the image is beyond the centre of curvature.

31. The radar antenna is in the shape of a concave mirror (parabola), so it has a focal point. The radio wave generator and detector are located at the focal point. The generated pulse starts from this point and is reflected from the mirror to the sky parallel to the principal axis. Any radio waves that return are parallel. After reflection, they are directed to the focal point, which then acts as a detector.

32. d_o = 35 cm; d_i = 10 cm; f = ?
$1/f = 1/d_o + 1/d_i$; $1/f = 1/35 + 1/10$
f = 7.8 cm



Section 10.4 Review

Images in Convex Mirrors

Answers for page 150

Multiple Choice

1. c

2. d

3. d

4. e

5. c

6. c

7. a

8. d

Answers for page 151

Written Answer

9. The rays that come parallel to the principal axis reflect outward from a convex mirror (away from the principal axis). However, they *appear* to come from a point behind the mirror, which is called the focal point.

10. The rays do not actually focus at the focal point. They *appear* to focus at the focal point, so it is called a *virtual* focal point.

11. The object is in front of the mirror, so the object distance measured from the mirror to the object is taken as the positive direction. The focal length is measured in a direction opposite to the object distance, so it is negative.

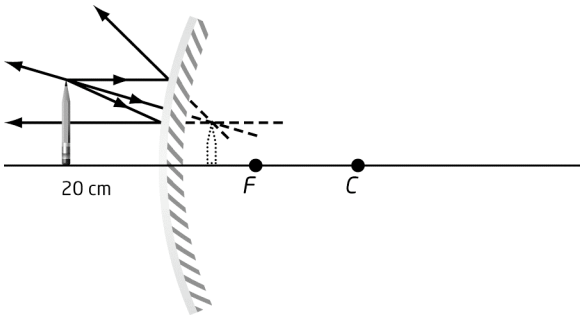
12. The object is in front of the mirror, so the object distance is taken as the positive direction. The image is always formed behind the mirror, and the image distance is measured in a direction opposite to the object distance. Therefore, it is negative.

13. The rounded surfaces of passenger aircraft act like convex mirrors, so the radar waves return to the antenna. Air traffic controllers on the ground want to know where passenger aircraft are. The stealth aircraft are military and need to avoid detection by air traffic controllers in other countries.

14. The image produced by a convex mirror is smaller than the object, virtual, behind the mirror, and upright.

15. The image in a convex mirror is smaller than the object and upright, which means that $h_i < h_o$ and both are positive. Therefore, the magnification, which is a ratio of h_i to h_o, is positive and less than 1.

16. $d_o = 20$ cm; $d_i = -10$ cm; $f = ?$
$1/f = 1/d_o + 1/d_i$; $1/f = 1/20 + 1/-10$
$f = -20$ cm



Chapter 10 Review

Light and Reflection

Answers for page 152

Multiple Choice

1. e

2. d

3. a

4. d

5. b

6. c

7. d

8. d

Answers for page 153

Written Answer

9. The image is virtual and upright.

10. With spherical aberration, reflected rays do not all go through the focal point.

11. The wavelength of visible light is 400 nm to 700 nm.

12. A convex mirror cannot produce an inverted image.

13. The fact that light travels in straight lines allows you to predict the sizes and shapes of shadows formed by opaque objects.

14. The focal length is half the radius of curvature.

15. The image will be larger than the object, real, and inverted.

16. The object should be moved closer to the mirror.

Answers for page 154

17. During the day, the phosphorescent algae absorb the light from the Sun and store it. At the end of the day, they emit this energy naturally in the form of light.

18. Researchers implanted a gene from jellyfish into zebrafish to make them absorb energy from an ultraviolet source. When these zebrafish are exposed to an ultraviolet source, they

emit energy in the form of visible light.

19. The black dragonfish has bioluminescent light organs under its eyes. It uses them like a flashlight to search for prey.

20. Heating is the most common way of producing light (in a bulb or a fire). Another way is for the object to absorb some kind of electromagnetic energy, such as ultraviolet.

21. A fluorescent bulb contains mercury vapour at very low pressure, with traces of an inert gas like argon. The inside of the bulb is coated with a phosphorescent material called phosphor. When the ballast is connected to a power supply and gets charged, it emits electrons. These electrons travel through the gas, from one electrode to another. As the electrons travel through the gas, they collide with atoms of mercury and excite these atoms. The excited mercury atoms release their excess energy in the form of ultraviolet rays, which human eyes cannot see. The energy of the ultraviolet rays is absorbed by the phosphor, which emits visible light.

22.

Light Bulb	Efficiency	Disposal	Lifetime
Incandescent	5%	garbage	many hours
Fluorescent	20%	require special facilities to dispose of them because of the toxic mercury contained within each bulb	much longer than incandescent

23. Suggested answers: Many body fluids (including blood, urine, and semen) contain fluorescent molecules. Forensic scientists use ultraviolet lights at crime scenes to find evidence in the form of body fluids. The tongue's natural fluorescence changes when abnormal tissue is present. A dentist or hygienist can shine a blue light in the mouth and look through a special filter to detect unhealthy oral tissue, which appears as very dark spots. Fluorescent materials are used in many types of documents. Banks, businesses, and other organizations have detectors that use ultraviolet lights to check documents and money to determine whether they are counterfeit. Some theatre performers use paint with fluorescent dyes. They perform in a dark theatre in which only ultraviolet light is shining.

24. Engineers put a convex mirror at the front of a school bus to help the driver see children as they pass in front of the bus.

Answers for page 155
25. *Sample answer*: you could have two plane mirrors facing together and parallel to each other and see the reflections of reflections over and over.

26. If a parabolic mirror reflects all light rays through the focal point, then there must be no spherical aberration. The images produced would be better than those produced by a concave mirror that was not parabolic in shape.

27. If it comes from a word that means "to rub," then triboluminescence may be produced by rubbing a substance until it emits light.

28. $f = 44$ cm; $d_o = 44/2 = 22$ cm; $d_i = ?$

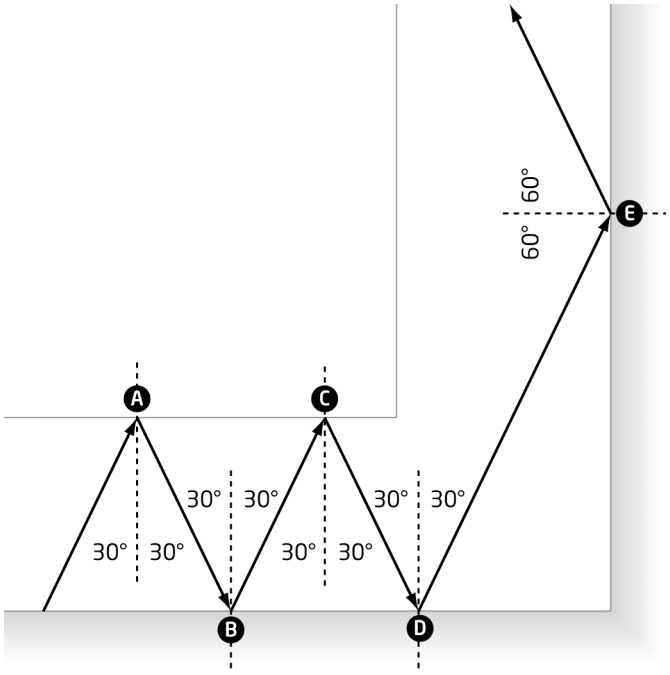
$1/f = 1/d_o + 1/d_i$; $1/d_i = 1/f - 1/d_o$; $1/d_i = 1/44 - 1/22$
$d_i = -44$ cm

29. The value of d_i is negative, so the image is behind the mirror. It is virtual because it is behind the mirror. The value $m = -d_i/d_o$ will be positive; m is greater than 1 ($m = -(-44/22) = 2.0$), so the image is larger than the object and upright.

30. $f = -25$ cm; $d_i = -15$ cm; $d_o = ?$
$1/f = 1/d_o + 1/d_i$; $1/d_o = 1/f - 1/d_i$; $1/d_o = -1/25 - (-1/15)$
$1/d_o = -1/25 + 1/15$
$d_o = 37.5$ cm

31. 1. Draw a ray starting at the top of the object parallel to the principal axis toward the concave mirror. Draw the reflected ray through the focal point. 2. Draw another ray from the top of the object through the focal point until it meets the concave mirror. Draw the reflected ray parallel to the principal axis. 3. Draw a ray from the top of the object as though it were coming from the centre of curvature. The point where all reflected rays meet is the top of the image.

32. The angle of reflection is 60°.



Chapter 11.1 Review

Refraction of Light

Answers for page 156

Multiple Choice

1. b

2. d

3. c

4. a

5. c

6. b

7. a

8. e

Answers for page 157

9. e

10. a

11. b

12. c

13. b

14. d

15. b

16. d

Answers for page 158

Written Answer

17. When a ray goes from one medium to another, its speed and direction change. This phenomenon is called refraction.

18. When light goes through a single medium, it travels in a straight line and at a constant speed.

19. When light enters a different medium at an angle (for example, when it moves from air to water), and the second medium has a different index of refraction, the light rays refract (bend), and the speed of light changes.

20. As the speed of light changes when it changes media, its direction changes, which means it bends.

21. $n = c/v = (3.0 \times 10^8 \text{ m/s})/(2.0 \times 10^8 \text{ m/s}) = 1.5$

22. The angle of refraction is the angle between the normal and the refracted ray.

23. Dispersion is the spreading out of white light into its component colours. It is caused by light of different colours refracting different amounts.

24. From highest to lowest index of refraction, the order is C, A, and B.

Answers for page 159

25. Every colour in the visible spectrum has a different speed in media other than a vacuum. So, when white light travels through a prism, each colour travels with a different speed and bends differently.

26. The seven main colours are red, orange, yellow, green, blue, indigo, and violet.

27. All gases are affected by temperature, pressure, and type of gas.

28. Liquids and solids are affected by temperature (and, to a lesser extent, by pressure) and the type of solid or liquid.

29. $n = c/v$; $v = c/n = 3 \times 10^8 \text{ m/s}/1.54 = 1.95 \times 10^8 \text{ m/s}$

30. Red bends the least, so it travels the fastest in the prism. Violet bends the most, so it travels the slowest.

31. You could pass a ray of light through each object. The object in which the light bends more has a higher index of refraction, so that is the medium in which light travels slowest.

32. $n = c/v$; $v = c/n = (3.00 \times 10^8 \text{ m/s})/1.35 = 2.22 \times 10^8 \text{ m/s}$

Section 11.2 Review

Partial Refraction and Total Internal Reflection

Answers for page 160

Multiple Choice

1. c

2. b

3. d

4. a

5. b

6. a

7. b

8. b

Answers for page 161

9. d

10. b

11. b

12. b

13. a

14. d

15. b

16. d

Answers for page 162

Written Answer

17. The first factor is the angle of incidence. As the angle of incidence increases, the amount of reflection increases and the amount of refraction decreases. The second factor is the value of the relative indices of refraction of the two media through which the light travels.

18. The amount of partial reflection from a transparent surface increases as the angle of

incidence of light increases. At sunset, the angle of incidence of sunlight on the surface of a lake is large, so most of it is reflected. This makes the surface appear very bright. During the day, when the Sun is overhead, and the angle of incidence is small and partial reflection is less. Thus, the water surface does not appear as bright.

19. The swimmer can see an object if the light rays that are coming from it are refracted through the water. The light rays coming from objects on the side have a large angle of incidence, so there is more partial reflection than refraction. Therefore, these objects are not visible to the swimmer.

20. The swimmer can see an object directly above her because the light rays that are coming from the object are refracted through water. For an object directly above her, the angle of incidence is small so there is less partial reflection. Most of the light is refracted toward the swimmer, so she would be able to see the object.

21. Light bends away from the normal when it passes from a slower to a faster medium. At the critical angle, the ray passes along the surface of the second medium, and the angle of refraction is 90°. If the angle of incidence is made greater than the critical angle, a ray of light does not get refracted. It gets totally reflected in the first medium and no refraction takes place. This is called total internal reflection.

22. Three technologies that use total internal reflection are periscopes, binoculars, and fibre optics.

23. There is no critical angle for light travelling from air to water. For total internal reflection to occur, light has to travel from a medium in which its speed is slower to a medium in which its speed is faster.

24. You can use the phenomenon of total internal reflection and an optical fibre to make light travel in circles. Shape an optical fibre into a circle, and shine a light through one end parallel to the principal axis of the optical fibre. The light will follow the shape of the optical fibre, and thus travel in a circle.

Answers for page 163

25. The ray of light coming from the left is incident on the left surface of the prism along the normal. Hence, it passes straight through without refracting. It is then incident on the opposite surface of the prism at an angle of 45°. The critical angle for glass to air is less than 45°, so this ray is totally internally reflected, as shown. This reflected ray hits the lower surface of the prism along the normal and passes straight through.

26. Retroreflectors are small plastic prisms that use total internal reflection to change the direction of light by 180°. When the light from a car's headlights hits the reflectors, it is always reflected directly back to the car so the car driver can see the bicycle.

27. Two uses of fibre optics technology are in the telecommunications industry and in surgical instruments.

28. Rearview mirrors are wedge-shaped and silvered on the back. A lever allows the driver to flip a rearview mirror from daytime to nighttime positions quickly. Light coming from behind the car hits the mirror at a very small angle of incidence. As a result, most of the light is refracted and reaches the silvered back of the mirror, where it is reflected.

29. Most rearview mirrors have a lever that allows the driver to choose how much light from behind the car will reach his or her eyes. During the day, the driver wants to clearly see the traffic that is behind the car. At night, however, the driver does not want to be blinded by light from the headlights of other cars.

30. There is no refraction of light when light is incident on the silvered surface of a mirror. Therefore, the reflection is not partial. When light is incident on the surface of water, it is partially reflected and partially refracted.

31. Reflection from a mirror occurs because a mirror is a shiny, opaque surface and no refraction can take place. Total internal reflection takes place when a ray of light is incident from a slow transparent to a fast transparent medium and the angle of incidence is greater than the critical angle. Also, with reflection from a mirror, the light can travel back in the opposite direction; however, with total internal reflection, the reflected light travels at 90˜ relative to the normal.

32. The light coming from the area directly above a swimmer or at a small angle of incidence penetrates the surface of the water, refracts, and is visible to the swimmer. But as the angle of incidence increases, more of the light reflects off the water, so a smaller amount refracts and is visible to the swimmer. Nearly all the light that is coming toward the swimmer from large angles of incidence will reflect from the surface and never reach the swimmer. Therefore, from below the surface of the water, it looks like light is coming through a hole.

Section 11.3 Review

Optical Phenomena in Nature

Answers for page 164

Multiple Choice

1. e

2. e

3. b

4. d

5. b

6. d

7. d

8. d

Answers for page 165

Written Answer

9. A rainbow is formed when sunlight enters a water droplet, refracts, then reflects off the inner surface of the droplet, and then refracts again when leaving the droplet. The two refractions result in dispersion of the light. The different colours cross each other, and then spread out as they leave the droplet.

10. A secondary rainbow is formed when sunlight reflects twice inside rain droplets. This explains why the secondary bow is less bright, and why red is at the bottom and blue is at the top, that is, the colours are arranged opposite to those in a single rainbow.

11. The Sun must be behind you because the rays have to reach the water droplets in the air and then reflect off the rays to your eyes. For this to happen, the light source has to be behind you.

12. Sundogs form when ice crystals in the atmosphere refract sunlight and the Sun is low, near the horizon.

13. Rainbows are a result of sunlight interacting with water droplets in the atmosphere. Sundogs occur when ice crystals in the atmosphere refract sunlight.

14. The light rays coming from the object at the bottom of the swimming pool refract at the surface of the water. The refracted rays bend away from the normal. For the observer outside, these rays appear to be coming from a point above the object. Therefore, the depth of the object appears to be less than the actual depth. This is called apparent depth.

15. Shimmering and mirages are caused by the refraction of light in unevenly heated air. When light travels through air that is at different temperatures, it refracts because hot air is less dense than cooler air. Because there is no distinct boundary between sections of air at different temperatures, the light does not bend at one specific point. Instead, it travels along a curved path. Also, because air is usually moving, the direction and the amount of the bending are constantly changing.

16. Ultraviolet radiation is one of the more energetic types of light in the electromagnetic spectrum. If your skin is exposed to sunlight for too long, you can get a sunburn. Also, you could damage your eyes if you do not protect them from ultraviolet radiation.

Chapter 11 Review

Refraction

Answers for page 166

Multiple Choice

1. b

2. d

3. c

4. a

5. e

6. c

7. d

8. c

Answers for page 167

Written Answer

9. The ray bends *toward* the normal.

10. Total internal reflection is possible when the light travels from the oil to the water, and when the light travels from the oil to the air.

11. The image of the object would appear above its actual location.

12. You should aim the light at the image of the object.

13. The image will appear lower than it did before.

14. Sundogs are bright spots on both sides of the Sun. They look like mini suns, or imitation suns, so they are called "mock suns."

15. First, the signals in fibre optics cables are not affected by electrical storms, as they would be in copper wire cables. Second, fibre optics cables can carry many more signals over long distances, losing less energy than copper cables. Third, fibre optics cables are smaller and lighter than copper cables.

16. If the angle of incidence is increased in this situation, partial reflection increases.

Answers for page 168

17. Reflection of light takes place when a ray of light strikes any reflective surface. For refraction to occur, the ray of light has to travel through a transparent medium.

18. Angles *R* and *a* are equal to each other, and angles *i* and *b* are equal to each other.

19. *R* is smaller than *i*. This is because when the ray of light travels from air to glass, it bends *toward* the normal.

20. Angle *a* is smaller than *b*. This is because when the ray of light travels from glass to air, it bends *away from* the normal.

21. The incident ray and the emergent ray are parallel to each other.

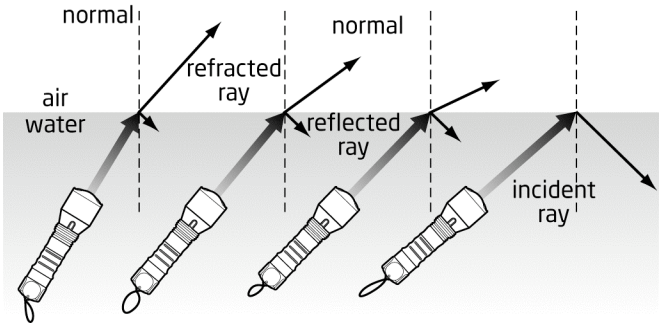
22. To get a critical angle, the ray of light must travel from a slow to a fast medium. But glass is a faster medium than diamond, so it is not possible to get a critical angle in this situation.

23. Whenever a ray of light travels from one transparent medium to another, it is partially reflected and partially refracted. But if the ray passes from a slow to a fast medium and the angle of incidence is greater than the critical angle, the ray *does not refract at all*. Rather, it reflects *totally and internally* back into the slow medium. Hence, this phenomenon is called total internal reflection.

24. If the speed of light were the same in all materials, light would not bend when crossing the boundary between air and water.

Answers for page 169

25.



26. As the incident ray from the flashlight makes a larger angle of incidence, less light is refracted but more light is reflected back in the water. In the last diagram, the critical angle has been reached and all the light is reflected back in the water.

27. $n = c/v$; $n = (3.00 \times 10^8 \text{ m/s})/(2.05 \times 10^8 \text{ m/s}) = 1.46$. The solid is quartz.

28. The ray of light must be incident at an angle greater than 24° for the light to be totally internally reflected.

29. The index of refraction of water is higher than that of air, so the critical angle for diamond in the water is larger. Therefore, less light is totally internally reflected and the diamond does not shine as brightly.

30. To identify a clear solid, I would use a flashlight, a protractor, and a table of different indices of refraction for several solids. I would shine the flashlight into the clear solid and measure the angle of refraction. If the angle of refraction is small, then the solid's index of refraction is close to 1. If the angle of refraction is large, then the solid's index of refraction is much higher than 1. I would then choose a likely solid from the table, using the type of solid as well, that is, whether the solid is a type of plastic, glass, or rock.

31. No, oil cannot do that. The teacher must have already had a whole Pyrex block in the beaker. The index of refraction of Pyrex and the vegetable oil must be the same. There would be no refraction, and the students wouldn't be able to see the whole Pyrex block already in the beaker.

32. In part A, the light is travelling from a medium in which the index of refraction is lower than the medium it is entering. Therefore, the refracted ray should bend toward the normal, not away from the normal. In part B, the refracted ray has bent so much that it has crossed the normal. This cannot happen.

Section 12.1 Review

Characteristics of Lenses

Answers for page 170

Multiple Choice

1. e

2. d

3. b

4. a

5. d

6. d

7. d

8. d

Answers for page 171

Written Answer

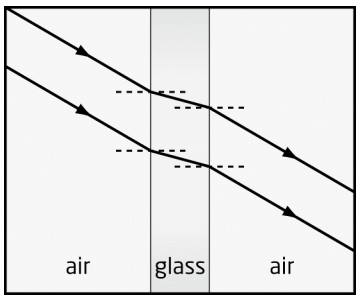
9. A lens is a transparent object with at least one curved side that causes light to refract.

10. A liquid lens can change shape, and the shape changes the focal length of the lens. As a result, a liquid lens does not need to move in and out to focus. A liquid lens is tiny, so it can be used in applications such as cellphones. The focus can be adjusted electronically, and since the lens is embedded in technology, the focussing is done electronically rather than manually.

11. A liquid lens consists of two liquids sealed in a transparent tube. The liquids have different indices of refraction, and they will not mix together.

12. The shape of the surface between the liquids determines the focal length of the lens. Once the lens is placed in its holder, electrical leads send a potential difference across the tube. The potential difference alters the lens properties such that the shape of the surface between the two fluids changes. The precise shape of the surface, and therefore the focal length of the lens, is controlled by the potential difference.

13. When parallel light rays pass through a flat piece of glass such as a window pane, the rays shift to the side but do not change their direction relative to each other. This is called lateral displacement.



14. In a converging lens, all the rays coming parallel to the principal axis, after refraction, converge at a point. This point is called the focal point. The image is *real*. In a diverging lens, all the rays that come parallel to the principal axis, after refraction, diverge and *appear* to come from a point on the same side as the incident rays. This point is called the focal point. The image is *virtual*.

15. Lenses with the same shape but with higher indices of refraction bend rays more, which positions the focal point closer to the lens.

16. Lenses with larger curvatures but with the same index of refraction have different focal lengths. As the curvature of the lens increases, the focal length decreases.

Section 12.2 Review

Images Formed by Lenses

Answers for page 172

Multiple Choice

1. d

2. d

3. c

4. a

5. b

6. b

7. d

8. a

Answers for page 173

9. b

10. e

11. d

12. e

13. b

14. c

15. b

16. b

Answers for page 174

Written Answer

17. When an object is placed between F and a converging lens, the rays of light, after refracting through the lens, diverge and do not meet anywhere. These rays appear to be coming from another point on the other side (the object's side) of the lens, and they form a virtual image there.

18. $d_i = ?$; $1/f = 1/d_o + 1/d_i$; $1/f - 1/d_o = 1/d_i$; $1/15 - 1/40 = 1/d_i$; $d_i = 24$ cm

19. $m = -d_i/d_o = -24/40 = -0.6$

20. $m = h_i/h_o$; $h_i = mh_o = (-0.6)(5\text{ cm}) = -3.0\text{ cm}$

21. Since m is less than 1, the image is smaller than the object. Since m is negative, the image is inverted and real. The image distance is 24 cm, so it is between F and $2F$.

22. $d_i = ?$; $1/f = 1/d_o + 1/d_i$; $1/f - 1/d_o = 1/d_i$; $1/15 - 1/10 = 1/d_i$; $d_i = -30\text{ cm}$

23. $m = -d_i/d_o = -(-30\text{ cm})/10\text{ cm} = 3.0$

24. The image is larger than the object, upright, virtual, and on the same side of the lens as the object.

Answers for page 175

25. The object must be placed between the lens and F, or between F and $2F$.

26. Since it is a diverging lens, the focal length and the image distance are negative.
$f = -20\text{ cm}$; $1/f - 1/d_i = 1/d_o$; $1/-20 - 1/-10 = 1/d_o$
$d_o = 20\text{ cm}$

27. $m = -d_i/d_o = -(-10\text{ cm})/20\text{ cm} = 0.5$

28. $m = h_i/h_o$; $h_i = mh_o = (0.5)(10\text{ cm}) = 5.0\text{ cm}$

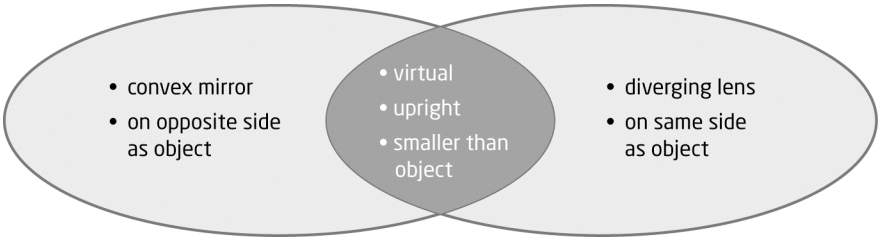
29. Since m is less than 1, the image is smaller than the object. Since m is positive, the image is upright and virtual. The image is on the same side of the lens as the object.

30. a. The lens is converging. Diverging lenses never create real images. **b.** The image is real and smaller than the object, so the object was beyond $2F$.

31.

Position of the Object	Position of the Image	Image Characteristics
Between F and the lens	Same side as the object	Virtual, upright, larger than the object
Between F and $2F$	Beyond $2F$	Real, inverted, larger than the object
At $2F$	At $2F$	Real, inverted, same size as the object
Beyond $2F$	Between F and $2F$	Real, inverted, smaller than the object

32.


• convex mirror
• on opposite side as object
• virtual
• upright
• smaller than object
• diverging lens
• on same side as object

Section 12.3 Review

Lens Technologies and the Human Eye

Answers for page 176

Multiple Choice

1. d

2. d

3. d

4. b

5. d

6. d

7. b

8. c

Answers for page 177

9. a

10. b

11. d

12. e

13. c

14. b

15. a

16. c

Answers for page 178

Written Answer

17. Most modern telescopes are reflecting telescopes because a large objective lens is more difficult to make than a large mirror.

18. Galileo's telescope had two lenses, one of which was converging and the other was a diverging lens. Light enters the telescope through the converging lens, which is called the

objective lens. The diverging lens is used as the eyepiece, through which the observer looks.

19. Kepler modified the design of Galileo's telescope to get greater magnification.

20. The improved magnification produced inverted images. Although this did not matter while studying the skies, it was a problem while studying terrestrial objects.

21. The figure shows Newton's telescope, or a reflecting telescope.

22. Microscopes are used in many applications, such as studying human cells, animal cells, and minerals. Some doctors and medical researchers use microscopes to investigate diseases and even figure out the cause of a person's death.

23. The pupil is an opening. Light enters the eye through the pupil.

24.

Human Eye Defect	Description
Myopia	Near-sightedness; the condition in which the eye cannot focus on distant objects
Hyperopia	Far-sightedness; the condition in which the eye cannot focus on nearby objects
Presbyopia	The condition in which lenses of the eye become stiff and the ciliary muscles can no longer make the lenses change shape
Astigmatism	Blurred or distorted vision usually caused by an incorrectly shaped cornea

Answers for page 179

25. Defects in the human eye are corrected with eyeglasses, contact lenses, and surgery.

26. Military and law-enforcement personnel can use night-vision devices to intensify the available light and enable them to see when it is dark.

27. Some risks for laser eye surgery are dry eyes; oversensitivity to light; poor perception of contrast; double vision; and perception of ghosted images, starbursts, or halos around light sources.

28. Presbyopia is the condition in which lenses of the eyes become stiff and the ciliary muscles can no longer make the lenses change shape. This happens when a person ages. People who have presbyopia cannot focus on nearby objects. When people are already near-sighted and they get presbyopia, they cannot focus on either distant or nearby objects. To correct this condition, people wear bifocals, which are lenses with two parts. The top part of the lens corrects for near-sightedness, and a small section of the lower part helps the eyes focus on nearby objects. Bifocal contact lenses are also available.

29. The cornea is a part of the human eye. It is a tissue that forms a transparent, curved structure in the front of the eye. It refracts light before it enters the eye.

30. The retina is the screen at the back of the eye where the image is formed. It is a layer of rod and cone cells that respond to light and initiate nerve impulses. Rod cells are very

sensitive to light but cannot distinguish between colours. Colours are detected by the cone cells.

31. The diagram shows how far-sightedness (or hyperopia) is corrected with a converging lens. Far-sightedness is a human eye defect that causes the light rays to focus behind the retina rather than on it. This results in a blurred image. The corrective converging lens bends the rays a little, bringing them closer together before they reach the cornea. The lens of the eye then refracts the rays a little more, and the rays are focussed on the retina.

32. Modern laser surgery uses the excimer laser, which is a form of ultraviolet laser. Instead of burning the tissue, this laser ablates (vaporizes) it to reshape parts of the cornea.

Chapter 12 Review

Lenses and Lens Technologies

Answers for page 180

Multiple Choice

1. e

2. b

3. b

4. b

5. c

6. d

7. a

8. b

Answers for page 181

Written Answer

9. The image will be larger than the object, real, and inverted.

10. $d_i = 17$ cm and $m = -0.67$

11. The object must be beyond F.

12. Microscopes are used to magnify small specimens.

13. A camera is designed to be like the human eye.

14. Binoculars are like two refracting telescopes put together.

15. The objective lens or mirror must be made bigger.

16. The image is virtual and inverted.

Answers for page 182

17. Reading stones have one convex side and one plane side. They were developed to magnify print on a page. The reader moved the stone across the page and read a few words at a time.

18. a. $d_i = 1/f - 1/d_o = 1/10 \text{ cm} - 1/8 \text{ cm} = -40 \text{ cm}$ **b.** $m = -d_i / d_o = -(-40 \text{ cm})/8 \text{ cm} = 5$; the value is positive so the image is upright.

19. If there was only one lens, the image would be real and smaller than the image produced with two lenses. It would be on the opposite side of the objective lens compared with the position of the object.

20. In a Kepler telescope, the two converging lenses are placed so that their focal points (F_1 and F_2) are at the same point between the lenses. Light from distant objects enters through the objective lens and forms an inverted, real image at a point close to F_1 and F_2. The image formed by the objective lens becomes the object for the eyepiece lens and is between F_2 and the eyepiece. Light from this image then passes through the eyepiece lens and forms a virtual image (because the first image is between F and the eyepiece) that appears to come from just beyond the objective lens. This is the final image, which is virtual and larger than the image formed by the objective lens. It is also inverted (as is the first image).

21. A person who has had laser surgery has improved vision that needs little or no correction with glasses or contact lenses.

22. Owls are nocturnal animal, so they hunt for prey at night. There is very little light at night, so owls need more rod cells to see.

23. The ciliary muscles are attached to the lens in the human eye. The muscles stretch or compress the lens and change its shape, thus changing its focal length This allows the lens to focus light from both nearby and distant objects on the retina.

24. The iris is the coloured tissue that surrounds the pupil. The iris can increase or decrease the size of the pupil to control the amount of light that enters the eye.

Answers for page 183

25. Binoculars are two refracting Kepler telescopes attached so that both eyes see the same image. Binoculars have two prisms on each side that use total internal reflection. Reflecting through the prisms makes the light path longer, and this provides better magnification. The prisms are oriented such that the image is upright when it reaches the observer's eye.

26. The two lenses in a microscope are a small objective lenses and a large eyepiece (also called the ocular lens). The focal length of the objective lens is also smaller than that of the eyepiece. The light rays from the specimen reach the objective lens, which refracts them to form an inverted, real image between the lenses. This image is formed between F_2 and the eyepiece. Rays from this image pass through the eyepiece, which again refracts the rays to form the final inverted, virtual, larger image for the observer to see.

27. Real images are always inverted.

28. The image formed on the retina is real, and real images are always inverted.

29. A person with hyperopia (far-sightedness) cannot focus on nearby objects. This condition results from an eyeball that is too short. Because of this, the light rays coming from a nearby object reach the retina before they meet. This makes the image formed on the retina blurry. This defect can be corrected with contact lenses that are converging lenses. The corrective lens in front of the eyes lens bends the rays a little, bringing them closer together before they reach the cornea. The lens of the eye then refracts the rays a little more, and the rays are focussed on the retina.

30. a. $m = h_i/h_o$. set equal to 2: $h_i/h_o = 2$; $h_o = h_i/2$. When $m = 2$, the object is half the size of the image. **b.** This can only be true for a converging lens because a diverging lens always produces an image that is smaller than the object.

31. For an object past the focal point of a converging lens, as the object distance increases, the image comes closer to the lens, which means that the image distance decreases.

32. $d_o = 5$ cm; $m = -d_i/d_o$. Set equal to 10: $-d_i/d_o = 10$; $d_i = -10d_o = (-10)(5\text{ cm}) = -50$ cm; $1/f = 1/d_i + 1/d_o = 1/-50\text{ cm} + 1/5\text{ cm}$; $f = 5$ cm

Unit 4 Review

Light and Geometric Optics

Answers for page 184

Written Answer

1. Light enters the cornea from air and it bends because the index of refraction for the cornea is higher than the index of refraction for air. When light moves from the cornea to the lens, it does bend some more but not as much because the index of refraction for the lens is close to the index of refraction for the cornea.

2. Some fish are genetically engineered to make them glow as a novelty for aquariums. Environmentalists are concerned about this because some of these genetically modified fish might be released into streams and ponds and disrupt the populations of natural fish.

3. *Sample answer*: Meet me after school!

Meet me after school!

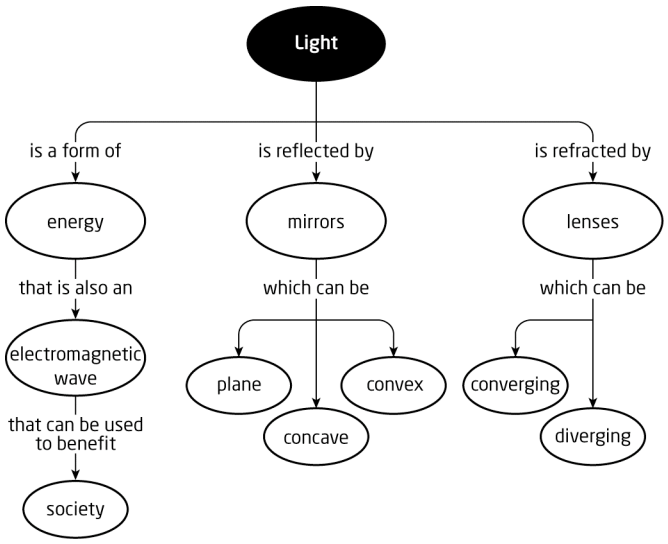
4. Many marine organisms use bioluminescence as a form of communication, to confuse predators, and to attract mates.

5. Fibre optic cables use light and the phenomenon of total internal reflection. The light within the cable can be transferred through large distances.

6. Endoscopy is one of the procedures that uses fibre optics technology. Because of this, surgeons no longer have to make large incisions in a patient. An endoscope is a bundle of optical fibres that carries light into the area where the surgery is needed. They are inserted in a patient by making a small incision. This bundle of optical fibres carries light by total internal reflection from the affected area to create an image and take it back to a computer monitor. The surgeon watches the monitor while manipulating the instrument to complete the surgery.

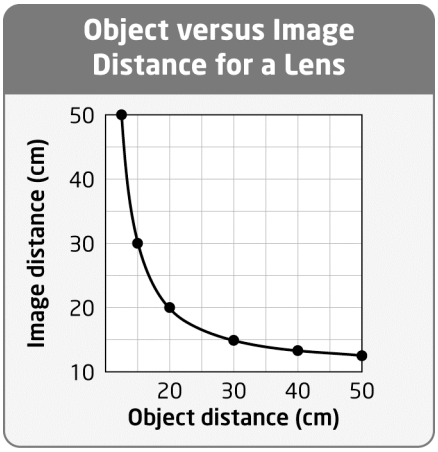
7. The curvature of lens A must be large compared with the curvature of lens B. The lenses have the same index of refraction, and lens A has a very short focal length. Lenses with short focal lengths have large curvatures, so the lens curvature of lens A must be greater than the lens curvature of lens B.

8.



Answers for page 185

9.



As the object moves closer to the lens, the distance of the image increases.

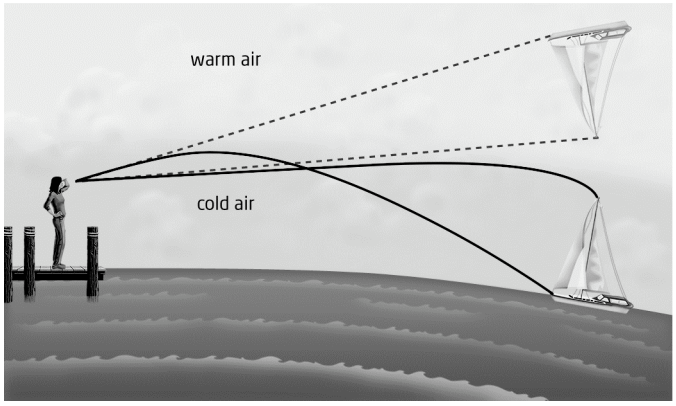
10. The focal length is given by the thin lens equation: $1/f = 1/d_i + d_o$. Take any pair of points from the table and substitute them into the thin lens equation: d_o = 15 cm and d_i = 30 cm; $1/f$ =1/30 cm + 1/15 cm = 3/30 cm; f = 10 cm. The focal length is 10 cm.

11. Sunlight contains ultraviolet radiation, which is one of the more energetic types of light in the electromagnetic spectrum. Overexposure to UV radiation can be dangerous. It can contribute to the development of cataracts, cancer, and snow blindness. You can also get a sunburn and damage your eyes if you do not protect yourself from overexposure to UV radiation.

12. $m = h_i/h_o$; $h_i = m\ h_o$ = 1000 □ 0.001 mm = 1 mm. The image has a diameter of about 1 mm.

13. In some places, warm winds blow over very cold oceans. This combination of extreme temperatures creates a weather condition called a temperature inversion. The light rays coming from a distant object, say, over the ocean, start to travel upward. The angle of

incidence increases, and at some point, total internal reflection occurs. No refraction takes place, and rays start travelling (reflecting) downward toward a distant observer. For the observer, these rays appear to be coming from a point that is higher than the actual object. This type of mirage creates an inverted image of the object above the ocean.



14. The fish will appear higher in the water than it actually is. The person with the light should focus light on the image of the fish. The person with the spear should aim under the image to get the fish.

15. *Sample answer*: One example of how light can be used is the stealth aircraft. The stealth aircraft is designed to make use of the reflecting properties of light. The surfaces of the stealth aircraft are flat and all the edges are sharp. When radar (a form of electromagnetic radiation) is sent from the ground, most of the radar rays will not hit perpendicular to these surfaces. When the rays reflect from the surfaces of the stealth aircraft, most of the reflected rays will not return to the radar antenna. This is desirable because the stealth aircraft is a military plane, and the military do not want it to be detected. If some of the rays do reflect back to the antenna, it will not be a problem because the signal will be so small that the radar operators will think that the aircraft is a small bird.

16. *Sample answer*: Aeronautic engineers modify aircraft designs to reduce air friction. To do this, they study the flow of air around a cone-shaped cylinder in a wind tunnel. As air hits the cone, it gets compressed in different ways. This creates different densities of air at different points. Air is transparent and cannot be seen. However, Schlieren photography is used to study these different densities of air. This technique uses the property of refraction to create the light and dark regions where changes in density occur. Then a computer converts the light and dark regions into different colours and makes the air "visible."

Answers for page 186

Literacy Test Prep

The Hubble Space Telescope

Multiple Choice

17. a

18. d

19. b

20. c

21. d

Written Answer

22. The curve of the HST's mirror was not quite good enough. It was too flat at the edges and was causing spherical aberration, which produced blurry images. Astronauts added new optical components to the mirror in 1993 that act like a pair of eyeglasses. This fixed the spherical aberration problem.

Answers for page 187

Literacy Test Prep

Laser Light and Its Applications

Multiple Choice

23. c

24. d

25. d

26. c

27. d

Written Answer

28. Laser light is just one wavelength, whereas white light is made up of several wavelengths. Also, laser light is more concentrated than white light.