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### Section 26.2 Snell's Law and the Refraction of Light

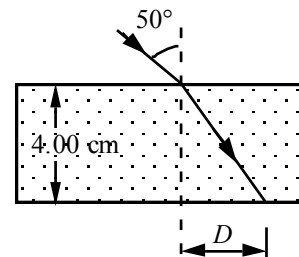
8. A beam of light passes from air into water. Which is necessarily true?
- (a) The frequency is unchanged and the *wavelength increases*.
  - (b) The frequency is unchanged and the *wavelength decreases*.
  - (c) The wavelength is unchanged and the *frequency decreases*.
  - (d) Both the wavelength and frequency *increase*.
  - (e) Both the wavelength and frequency *decrease*.

9. A ray of light passes from air into a block of glass with a refractive index of 1.50 as shown in the figure.

Note: *The drawing is not to scale.*

What is the value of the distance  $D$ ?

- (a) 1.42 cm
- (b) 1.66 cm
- (c) 1.90 cm
- (d) 2.14 cm
- (e) 2.38 cm



10. A fish swims 2.00 m below the surface of a pond. At what apparent depth does the fish appear to swim if viewed from directly above? The index of refraction of water is 1.33.

- (a) 1.33 m
- (b) 1.50 m
- (c) 2.00 m
- (d) 2.66 m
- (e) 3.00 m

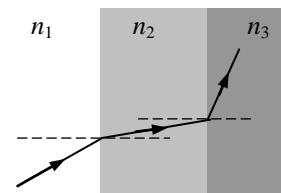
11. A grizzly bear is sitting on a rock in the middle of a calm river when she observes a fish directly below. If the apparent depth of the fish is 0.60 m, what is the actual depth at which the fish is swimming? The index of refraction of water is 1.33.

- (a) 0.80 m
- (b) 0.71 m
- (c) 0.62 m
- (d) 0.53 m
- (e) 0.45 m

13. The figure shows the path of a portion of a ray of light as it passes through three different materials. Note: *The figure is drawn to scale.*

What can be concluded concerning the refractive indices of these three materials?

- (a)  $n_1 < n_2 < n_3$
- (b)  $n_1 > n_2 > n_3$
- (c)  $n_3 < n_1 < n_2$
- (d)  $n_2 < n_1 < n_3$
- (e)  $n_1 < n_3 < n_2$



14. A ray of light propagates in water ( $n = 1.333$ ) and strikes a sheet of crown glass ( $n = 1.523$ ). If the angle of refraction in the glass is  $35.2^\circ$ , determine the angle of incidence.

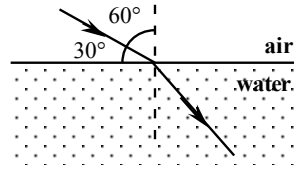
- (a)  $30.3^\circ$
- (b)  $32.8^\circ$
- (c)  $35.2^\circ$
- (d)  $41.2^\circ$
- (e)  $45.0^\circ$

15. Light with a wavelength of 589 nm in a vacuum strikes the surface of an unknown liquid at an angle of  $31.2^\circ$  with respect to the normal to the surface. If the light travels at a speed of  $1.97 \times 10^8$  m/s through the liquid, what is the angle of refraction?

- (a)  $19.9^\circ$
- (b)  $26.1^\circ$
- (c)  $34.2^\circ$
- (d)  $39.3^\circ$
- (e)  $51.9^\circ$

Questions 16 and 17 pertain to the statement and diagram below:

The figure shows the path of a ray of light as it travels through air and crosses a boundary into water. The index of refraction of water for this light is 1.33.

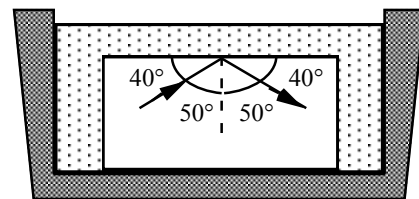


16. What is the speed of this ray of light as it travels through the water?
- (a)  $1.54 \times 10^8$  m/s      (c)  $2.86 \times 10^8$  m/s      (e)  $4.43 \times 10^9$  m/s  
 (b)  $2.26 \times 10^8$  m/s      (d)  $3.99 \times 10^8$  m/s
17. What is the angle of refraction for this situation?
- (a)  $0.37^\circ$       (c)  $22^\circ$       (e)  $60^\circ$   
 (b)  $0.65^\circ$       (d)  $41^\circ$

### Section 26.3 Total Internal Reflection

18. Complete the following statement: Fiber optics make use of
- (a) total internal reflection.      (c) chromatic aberration.      (e) dispersion.  
 (b) polarization.      (d) Brewster's angle.
19. Which one of the following expressions determines the critical angle for quartz ( $n = 1.5$ ) immersed in oil ( $n = 1.1$ )?
- (a)  $\theta_c = 1.5/1.1$       (c)  $\theta_c = \sin^{-1}(1.1/1.5)$       (e)  $\theta_c = \tan^{-1}(1.1/1.5)$   
 (b)  $\theta_c = 1.5/1.1$       (d)  $\theta_c = \sin(1.1/1.5)$
20. A ray of light originates in medium A and is incident upon medium B. For which one of the following pairs of indices of refraction for A and B is total internal reflection *not possible*?
- |     | $n_A$ | $n_B$ |
|-----|-------|-------|
| (a) | 1.36  | 1.00  |
| (b) | 1.26  | 1.15  |
| (c) | 2.54  | 1.63  |
| (d) | 1.28  | 1.36  |
| (e) | 1.12  | 1.06  |

21. A glass block with an index of refraction of 1.7 is immersed in an unknown liquid. A ray of light inside the block undergoes total internal reflection as shown in the figure. Which one of the following relations best indicates what may be concluded concerning the index of refraction of the liquid,  $n_L$ ?



- (a)  $n_L < 1.0$       (c)  $n_L \geq 1.3$       (e)  $n_L \leq 1.3$   
 (b)  $n_L \geq 1.1$       (d)  $n_L \leq 1.1$
22. A light ray is traveling in a diamond ( $n = 2.419$ ). If the ray approaches the diamond-air interface, what is the minimum angle of incidence that will result in all of the light reflected back into the diamond? The index of refraction for air is 1.000.
- (a)  $24.42^\circ$       (c)  $54.25^\circ$       (e)  $77.54^\circ$   
 (b)  $32.46^\circ$       (d)  $65.58^\circ$

- 23. A fiber optic line is composed of a core with an index of refraction of 1.47 and cladding with an index of 1.31. Which one of the following relations best describes angles of incidence  $\theta$  that will result in total internal reflection within the fiber optic line?
- (a)  $\theta < 63^\circ$  (c)  $\theta < 27^\circ$  (e)  $0 \leq \theta \leq 90^\circ$   
 (b)  $\theta > 63^\circ$  (d)  $\theta > 27^\circ$
- 24. Light propagates from soda lime glass ( $n = 1.518$ ) into Pyrex glass ( $n = 1.473$ ). Determine the critical angle for this situation.
- (a)  $13.99^\circ$  (c)  $52.48^\circ$  (e)  $76.01^\circ$   
 (b)  $45.86^\circ$  (d)  $65.22^\circ$

### Section 26.4 Polarization and the Reflection and Refraction of Light

- 26. A ray of light originating in oil ( $n = 1.21$ ) is incident at the *Brewster angle* upon a flat surface of a quartz crystal ( $n = 1.458$ ). Determine the angle of incidence for this ray.
- (a)  $0.82^\circ$  (c)  $40^\circ$  (e)  $56^\circ$   
 (b)  $1.2^\circ$  (d)  $50^\circ$
- 27. What is the Brewster angle if light is reflected from a plastic plate ( $n = 1.575$ ) submerged in ethyl alcohol ( $n = 1.362$ )?
- (a)  $68.3^\circ$  (c)  $59.8^\circ$  (e)  $49.1^\circ$   
 (b)  $40.8^\circ$  (d)  $30.1^\circ$

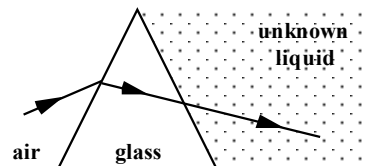
*Questions 28 and 29 pertain to the following situation.*

Light in air is incident on a plastic plate at the Brewster angle. The angle of refraction is  $35.0^\circ$ .

- 28. Determine the Brewster angle.
- (a)  $35.0^\circ$  (c)  $46.5^\circ$  (e)  $82.3^\circ$   
 (b)  $55.0^\circ$  (d)  $43.5^\circ$
- 29. What is the index of refraction of the plastic plate?
- (a) 1.58  
 (b) 1.36  
 (c) 1.43  
 (d) 1.61  
 (e) 1.74

### Section 26.5 The Dispersion of Light: Prisms and Rainbows

- 30. A ray of green light travels through air and is refracted as it enters a glass prism shown in the figure. An unknown liquid is in contact with the right side of the prism. The light then follows the path shown. Which one of the following statements concerning this situation is true?



- (a) The frequency of the light changes inside the prism.  
 (b) The index of refraction of the glass is smaller than that of air.  
 (c) The index of refraction of the unknown liquid is the same as that of the glass.  
 (d) The speed of light is larger in the liquid than in the glass.  
 (e) The refractive index of the liquid is the same as that of air.

- 31. Complete the following statement: The term *dispersion* refers to the fact that the index of refraction of certain materials
- (a) depends on the Brewster angle. (d) depends on the intensity of light.  
 (b) depends on the wavelength of light. (e) depends on the polarization of light.  
 (c) depends on the angle of incidence.
- 32. White light enters a glass prism, but the color components of the light are observed to emerge from the prism. Which one of the following statements best explains this observation?
- (a) The separation of white light into its color components is due to the increase in the speed of light within the glass.  
 (b) Some of the color components of the white light are absorbed by the glass and only the remaining components are observed.  
 (c) The index of refraction of the glass depends on the wavelength, so the color components are refracted at different angles.  
 (d) Only some of the color components are refracted by the glass; and these are the ones that are observed.  
 (e) White light is separated into its color components by total internal reflection within the prism.

### Section 26.6 Lenses

#### Section 26.7 The Formation of Images by Lenses

#### Section 26.8 The Thin-Lens Equation and the Magnification Equation

- 40. Which one of the following statements is true concerning the *focal length* of a lens?
- (a) The focal length is the same for all colors.  
 (b) The focal length is different for different colors because of reflection.  
 (c) The focal length is different for different colors because of dispersion.  
 (d) The focal length is different for different colors because of polarization.  
 (e) The focal length is different for different colors because of spherical aberration.
- 41. An object is placed at the focal point of a converging lens of focal length  $f$ . What is the image distance?
- (a)  $f$  (c)  $1/f$  (e) at an infinite distance  
 (b)  $2f$  (d)  $2/f$
- 42. An object is placed at the focal point of a thin diverging lens of focal length  $f$ . What is the image distance?
- (a)  $f$  (c)  $1/f$  (e) at an infinite distance  
 (b)  $2f$  (d)  $f/2$
- 43. An object is placed 4.0 cm from a thin converging lens with a focal length of 12 cm. Which one of the following statements is true concerning the image?
- (a) The image is virtual and 6.0 cm from the lens.  
 (b) The image is virtual and 12 cm from the lens.  
 (c) The image is real and 3.0 cm from the lens.  
 (d) The image is real and 6.0 cm from the lens.  
 (e) The image is real and 12 cm from the lens.
- 44. A converging lens is used to focus light from a small bulb onto a book. The lens has a focal length of 10.0 cm and is located 40.0 cm from the book. Determine the distance from the lens to the light bulb.



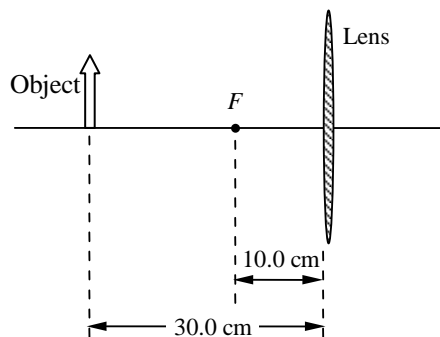


A diverging lens has a focal length of  $-10$  cm. A 3-cm object is placed 25 cm from the lens.

- 59. Determine the approximate distance between the object and the image.
- (a) 7 cm (c) 18 cm (e) 35 cm  
 (b) 10 cm (d) 32 cm
- 60. What is the magnification of the image?
- (a)  $+0.3$  (c)  $+0.7$  (e)  $+0.8$   
 (b)  $-0.3$  (d)  $-0.7$
- 61. Which pair of terms most accurately describes the image?
- (a) real, upright (c) real, inverted (e) real, reduced  
 (b) virtual, upright (d) virtual, inverted

**Questions 62 through 64 pertain to the statement and diagram below:**

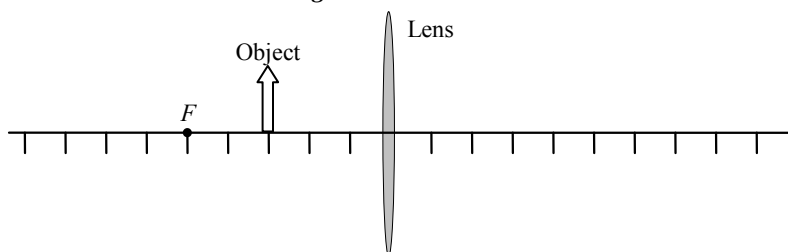
A 4.0-cm object is placed 30.0 cm from a converging lens that has a focal length of 10.0 cm as shown in the diagram. **Note:** *The diagram is not drawn to scale.*



- 62. Where is the image located?
- (a) 15 cm to the left of the lens (d) 15 cm to the right of the lens  
 (b) 7.5 cm to the left of the lens (e) 30 cm to the right of the lens  
 (c) 7.5 cm to the right of the lens
- 63. Determine the height and orientation of the image.
- (a) 2 cm and upright (c) 2 cm and inverted (e) 8 cm and inverted  
 (b) 1 cm and inverted (d) 8 cm and upright
- 64. A second converging lens is placed 20.0 cm to the right of the lens shown in the figure. Determine the focal length of the second lens if an inverted image (relative to the object in the diagram) is formed 13.3 cm to the right of the first lens.
- (a) 1.33 cm (c) 13.3 cm (e) 19.7 cm  
 (b) 6.67 cm (d) 15.4 cm

**Questions 65 through 67 pertain to the statement and diagram below:**

The figure is a scaled diagram of an object and a converging lens. The focal length of the lens is 5.0 units. An object is placed 3.0 units from the lens as shown.



- 65. Approximately, what is the image distance?
- (a)  $-2.0$  units (c)  $+6.0$  units (e)  $+9.0$  units  
 (b)  $-4.0$  units (d)  $-7.5$  units
- 66. The object has a height of 1.5 units. What is the approximate height of the image?

- (a) 2.0 units (c) 5.0 units (e) 9.8 units  
(b) 1.2 units (d) 3.8 units

- 67. Which pair of terms most accurately describes the image?  
(a) real, upright (c) real, inverted (e) virtual, upright  
(b) real, enlarged (d) virtual, inverted

### Section 26.10 The Human Eye

- 75. An object is placed 15 cm from a converging lens with a 5.0-diopter refractive power. At what distance from the object will the image be located?  
(a) 15 cm (c) 45 cm (e) 75 cm  
(b) 20 cm (d) 60 cm
- 76. Rachel has a far point of 5 m. Which statement below concerning Rachel's vision is true?  
(a) She has normal vision.  
(b) She is myopic and requires diverging lenses to correct her vision.  
(c) She is myopic and requires converging lenses to correct her vision.  
(d) She is hyperopic and requires diverging lenses to correct her vision.  
(e) She is hyperopic and requires converging lenses to correct her vision.
- 77. Without his contact lenses, Mr. Zheng can focus from 0.80 m to infinity. What refractive power of the lenses does he require for normal reading (0.25 m from the eyes)?  
(a) 1.25 diopters (c) 4.00 diopters (e) -5.25 diopters  
(b) 2.75 diopters (d) 5.25 diopters
- 78. The right lens of Josh's contact lenses is a converging lens of +2.50 diopters. He can read a book held as close as 25 cm from his eyes. Without his lenses, Josh's right eye has  
(a) a far point of 15.4 cm. (d) a near point of 15.4 cm.  
(b) a far point of 40.0 cm. (e) a near point of 66.7 cm.  
(c) a far point of 66.7 cm.
- 79. Mrs. York has been prescribed eyeglasses with lenses that have a +3.2-diopter refractive power. The glasses are worn 2.0 cm from her eyes. With the lenses, she can read a magazine held 25 cm from her eyes. Which one of the following statements is necessarily true?  
**Note:** The near points and far points given in the following answers are measured relative to her eye.  
(a) She has a far point of 3.2 m. (d) She has a near point of 6.4 m.  
(b) She has a far point of 0.25 m. (e) She has a near point of 0.87 m.  
(c) She has a near point of 3.2 m
- 80. Matthew's near point is 20.0 cm and his far point is 2.0 m. His contact lenses are designed so that he can see objects that are infinitely far away. What is the closest distance that he can see an object clearly when he wears his contacts?  
(a) 18 cm (c) 25 cm (e) 180 cm  
(b) 22 cm (d) 75 cm
- 81. In a scene from a movie, a nearsighted character removes his eyeglasses and uses them to focus the nearly parallel rays of the sun to start a fire. What is physically wrong with this scene?  
(a) The eyeglasses have diverging lenses and cannot be used to focus parallel rays.  
(b) The eyeglasses have converging lenses and cannot be used to focus parallel rays.  
(c) Sunlight cannot be used to start a fire.



- (d) A fire can only be started if the image is virtual.
  - (e) Parallel rays cannot be focused.
- 82. Light that is incident upon the eye is refracted several times before it reaches the retina. As light passes through the eye, at which boundary does the majority of the overall refraction occur?
- (a) lens/aqueous humor
  - (b) air/cornea
  - (c) lens/vitreous humor
  - (d) aqueous humor/iris
  - (e) vitreous humor/retina