Section 26.1 The Index of Refraction

1. The table lists the index of refraction for various substances at 20 °C for light with a wavelength of 589 nm in a vacuum. Through which substance will light with a vacuum wavelength of 589 nm travel with the greatest speed?

- (a) fused quartz
- (b) crown glass
- (c) ethyl alcohol
- (d) carbon tetrachloride
- (e) crystalline quartz

<table>
<thead>
<tr>
<th>Substance</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>fused quartz</td>
<td>1.458</td>
</tr>
<tr>
<td>ethyl alcohol</td>
<td>1.362</td>
</tr>
<tr>
<td>crown glass</td>
<td>1.520</td>
</tr>
<tr>
<td>carbon tetrachloride</td>
<td>1.461</td>
</tr>
<tr>
<td>crystalline quartz</td>
<td>1.544</td>
</tr>
</tbody>
</table>

2. Which one of the following statements concerning the index of refraction for a given material is true?

- (a) It may be less than 1.
- (b) It may be measured in nanometers.
- (c) It does not depend on the frequency of the incident light.
- (d) For a given frequency, it is inversely proportional to the wavelength of light in vacuum.
- (e) For a given frequency, it is inversely proportional to the wavelength of light in the material.

3. The bending of light as it moves from one medium to another with differing indices of refraction is due to a change in what property of the light?

- (a) amplitude
- (b) period
- (c) frequency
- (d) speed
- (e) color

4. When certain light rays pass from a vacuum into a block of an unknown material, the measured index of refraction of the material is 3.50. What is the speed of light inside the block?

- (a) $1.0 \times 10^7$ m/s
- (b) $4.8 \times 10^7$ m/s
- (c) $8.6 \times 10^7$ m/s
- (d) $1.9 \times 10^8$ m/s
- (e) $2.9 \times 10^8$ m/s

5. What is the frequency of light that has a wavelength in water of $6.00 \times 10^2$ nm if the refractive index for this light is 1.33?

- (a) $3.76 \times 10^{14}$ Hz
- (b) $5.00 \times 10^{14}$ Hz
- (c) $6.65 \times 10^{14}$ Hz
- (d) $7.25 \times 10^{14}$ Hz
- (e) $9.52 \times 10^{14}$ Hz

6. Blue light with a wavelength of 425 nm passes from a vacuum into a glass lens; and the index of refraction is found to be 1.65. The glass lens is replaced with a plastic lens. The index of refraction for the plastic lens is 1.54. In which one of the two lenses does the light have the greatest speed and what is that speed?

- (a) glass, $2.28 \times 10^8$ m/s
- (b) plastic, $2.13 \times 10^8$ m/s
- (c) glass, $1.82 \times 10^8$ m/s
- (d) plastic, $1.95 \times 10^8$ m/s
- (e) The speed of the blue light is the same in the vacuum and both lenses; and it is $3.00 \times 10^8$ m/s.

7. The speed of light in material A is 1.25 times as large as it is in material B. What is the ratio of the refractive indices, $n_A/n_B$, of these materials?

- (a) 1.50
- (b) 1.25
- (c) 1.00
- (d) 0.90
- (e) 0.800
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 (d) 2.14 cm
   (b) 1.66 cm (e) 2.38 cm
   (c) 1.90 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 (c) 2.00 m (e) 3.00 m
   (b) 1.50 m (d) 2.66 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 (c) 0.62 m (e) 0.45 m
   (b) 0.71 m (d) 0.53 m

12. A scuba diver shines a flashlight from beneath the surface of water (n = 1.33) such that the light strikes the water-air boundary with an angle of incidence of 43°. At what angle is the beam refracted?

   (a) 31° (c) 48° (e) 90°
   (b) 43° (d) 65°

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. Light with a wavelength of 589 nm in a vacuum strikes the surface of an unknown liquid at an angle of 31.2° 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° (c) 34.2° (e) 51.9°
   (b) 26.1° (d) 39.3°
15. 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°, determine the angle of incidence.

(a) 30.3°  
(b) 32.8°  
(c) 35.2°  
(d) 41.2°  
(e) 45.0°

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) \(1.54 \times 10^8 \text{ m/s}\)  
(b) \(2.26 \times 10^8 \text{ m/s}\)  
(c) \(2.86 \times 10^8 \text{ m/s}\)  
(d) \(3.99 \times 10^8 \text{ m/s}\)  
(e) \(4.43 \times 10^9 \text{ m/s}\)

17. What is the angle of refraction for this situation?

(a) 0.37°  
(b) 0.65°  
(c) 22°  
(d) 41°  
(e) 60°

Section 26.3 Total Internal Reflection

18. Complete the following statement: Fiber optics make use of

(a) total internal reflection.  
(b) polarization.  
(c) chromatic aberration.  
(d) Brewster’s angle.  
(e) dispersion.

19. Which one of the following expressions determines the critical angle for quartz \((n = 1.5)\) immersed in oil \((n = 1.1)\)?

(a) \(\theta_c = 1.5/1.1\)  
(b) \(\theta_c = 1.5/1.1\)  
(c) \(\theta_c = \sin^{-1}(1.1/1.5)\)  
(d) \(\theta_c = \tan^{-1}(1.1/1.5)\)  
(e) \(\theta_c = \sin(1.1/1.5)\)

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?

\[
\begin{array}{cc}
n_A & n_B \\
(a) & 1.36 & 1.00 \\
(b) & 1.26 & 1.15 \\
(c) & 2.54 & 1.63 \\
(d) & 1.28 & 1.36 \\
(e) & 1.12 & 1.06 \\
\end{array}
\]

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) \(n_L < 1.0\)  
(b) \(n_L \geq 1.1\)  
(c) \(n_L \geq 1.3\)  
(d) \(n_L \leq 1.1\)  
(e) \(n_L \leq 1.3\)
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 being reflected back into the diamond? The index of refraction for air is 1.000.
(a) 24.42° (c) 54.25° (e) 77.54°
(b) 32.46° (d) 65.58°

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) \( \theta < 63° \) (c) \( \theta < 27° \) (e) \( 0 \leq \theta \leq 90° \)
(b) \( \theta > 63° \) (d) \( \theta > 27° \)

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° (c) 52.48° (e) 76.01°
(b) 45.86° (d) 65.22°

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

25. A child is looking at a reflection of the sun in a pool of water. When she puts on a pair of Polaroid sunglasses with a vertical transmission axis, she can no longer see the reflection. At what angle is she looking at the pool of water?
(a) 45.0° (c) 53.1° (e) 77.3°
(b) 48.8° (d) 61.6°

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° (c) 40° (e) 56°
(b) 1.2° (d) 50°

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° (c) 59.8° (e) 49.1°
(b) 40.8° (d) 30.1°

**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°.

28. Determine the Brewster angle.
(a) 35.0° (c) 46.5° (e) 82.3°
(b) 55.0° (d) 43.5°

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.

Questions 33 and 34 pertain to the situation described below:

A ray of light is normally incident on face ab of a plastic prism with an index of refraction $n = 1.20$ as shown.

33. Determine the largest value of the angle $\alpha$ so that the ray is totally reflected at the face ac if the prism is immersed in air.

(a) 28° (c) 45° (e) Total internal reflection will not occur for any value of $\alpha$.
(b) 34° (d) 56°

34. Determine the largest value of the angle $\alpha$ so that the ray is totally reflected at the face ac if the prism is immersed in a liquid with refractive index 1.12.

(a) 21° (b) 34° (c) 69° (d) 78° (e) Total internal reflection will not occur for any value of $\alpha$. 
35. A certain type of glass is used in making flat-panel computer monitors. For light with a wavelength in air of 656.3 nm, the refractive index of the glass is \( n_A = 1.5160 \). For light with a wavelength in air of 435.8 nm, \( n_B = 1.5290 \). Determine the difference, \( \lambda_A - \lambda_B \), in their wavelengths inside the glass.

(a) 147.9 nm  
(b) 156.0 nm  
(c) 220.5 nm  
(d) 268.4 nm  
(e) 293.1 nm

Questions 36 through 39 pertain to the situation described below:

A beam of light that consists of a mixture of red, green, and violet light strikes a prism (surrounded by air) as shown. Indices of refraction for this prism for the various colors are indicated in the table. An observer is located to the right of the prism as shown.

<table>
<thead>
<tr>
<th>Color</th>
<th>( n )</th>
</tr>
</thead>
<tbody>
<tr>
<td>red</td>
<td>1.43</td>
</tr>
<tr>
<td>green</td>
<td>1.40</td>
</tr>
<tr>
<td>violet</td>
<td>1.37</td>
</tr>
</tbody>
</table>

36. Which color(s) could, in principle, be seen by the observer?

(a) only red light  
(b) only green light  
(c) only violet light  
(d) only green and red light  
(e) only green and violet light

37. Which physical phenomenon is illustrated by the fact that the observer will not see all three colors of light?

(a) Doppler effect  
(b) dispersion  
(c) diffraction  
(d) total internal reflection  
(e) interference

38. Which physical phenomenon is illustrated by the fact that the prism has different refractive indices for different colors?

(a) Doppler effect  
(b) dispersion  
(c) diffraction  
(d) total internal reflection  
(e) interference

39. Which physical phenomenon is illustrated by the fact that the emerging rays are spread into the component colors of the beam?

(a) Doppler effect  
(b) dispersion  
(c) diffraction  
(d) total internal reflection  
(e) interference

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) $f$  
(b) $2f$  
(c) $1/f$  
(d) $2/f$  
(e) at an infinite distance

42. An object is placed at the focal point of a thin diverging lens of focal length $f$. What is the image distance?

(a) $f$  
(b) $2f$  
(c) $1/f$  
(d) $f/2$  
(e) at an infinite distance

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) $8.6$ cm  
(b) $13$ cm  
(c) $20$ cm  
(d) $30$ cm  
(e) $50$ cm

45. When an object is placed $25$ cm from a lens, a real image is formed. Which one of the following conclusions is incorrect?

(a) The image is upright.
(b) The lens is a converging lens.
(c) The image may be reduced or enlarged.
(d) The image distance can be less than $25$ cm.
(e) The focal length of the lens is less than $25$ cm.

46. When an object is placed $15$ cm from a lens, a virtual image is formed. Which one of the following conclusions is incorrect?

(a) The lens may be a convex or concave.
(b) If the image is upright the lens must be a diverging lens.
(c) If the image is reduced, the lens must be a diverging lens.
(d) If the lens is a diverging lens, the image distance must be less than $15$ cm.
(e) If the lens is a converging lens, the focal length must be greater than $15$ cm.

47. When an object is placed $20$ cm from a diverging lens, a reduced image is formed. Which one of the following statements is necessarily true?

(a) The image is inverted.
(b) The image could be real.
(c) The image distance must be greater than $20$ cm.
(d) The focal length of the lens may be less than $20$ cm.
(e) The refractive power of the lens must be greater than $0.05$ diopters.

48. A $6.0$-cm object is placed $30.0$ cm from a lens. The resulting image height has a magnitude of $2.0$ cm; and the image is inverted. What is the focal length of the lens?

(a) $7.5$ cm  
(b) $15.0$ cm  
(c) $22.5$ cm  
(d) $30.0$ cm  
(e) $45.0$ cm
49. A converging lens with a focal length of 12 cm produces a 3-cm high virtual image of a 1-cm high object. Which entry in the table below is correct?

<table>
<thead>
<tr>
<th>image distance</th>
<th>location of image</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) 8 cm</td>
<td>same side of lens as object</td>
</tr>
<tr>
<td>(b) 8 cm</td>
<td>opposite side of lens from object</td>
</tr>
<tr>
<td>(c) 12 cm</td>
<td>opposite side of lens from object</td>
</tr>
<tr>
<td>(d) 24 cm</td>
<td>opposite side of lens from object</td>
</tr>
<tr>
<td>(e) 24 cm</td>
<td>same side of lens as object</td>
</tr>
</tbody>
</table>

50. A camera with a focal length of 0.0500 m (a 50-mm lens) is focused for an object at infinity. To focus the camera on a subject which is 4.00 m away, how should the lens be moved?

(a) 1.0 cm closer to the film
(b) 0.06 cm closer to the film
(c) 4.94 cm closer to the film
(d) 0.06 cm farther from the film
(e) 4.94 cm farther from the film

51. A 4-cm object is placed in front of a converging lens of focal length 20 cm. The image is formed 60 cm on the other side of the lens. Which entry in the table below is correct?

<table>
<thead>
<tr>
<th>object distance</th>
<th>magnitude of the image height</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) 15 cm</td>
<td>2 cm</td>
</tr>
<tr>
<td>(b) 15 cm</td>
<td>4 cm</td>
</tr>
<tr>
<td>(c) 30 cm</td>
<td>4 cm</td>
</tr>
<tr>
<td>(d) 30 cm</td>
<td>8 cm</td>
</tr>
<tr>
<td>(e) 60 cm</td>
<td>2 cm</td>
</tr>
</tbody>
</table>

52. A 2.00-cm tall object is placed 40.0 cm from a lens. The resulting image is 8.00-cm tall and upright relative to the object. Determine the focal length of the lens.

(a) 26.6 cm
(b) 32.0 cm
(c) 53.3 cm
(d) 64.0 cm
(e) 80.0 cm

53. In a slide projector, the slide is illuminated; and light passing through the slide then passes through a converging lens of focal length 0.10 m. If a screen is placed 5.0 m from the lens, a sharp image is observed. How far is the slide from the lens?

(a) 0.082 m
(b) 0.050 m
(c) 0.50 m
(d) 0.27 m
(e) 0.10 m

54. Joseph uses a converging lens (\( f = 0.12 \) m) to read a map located 0.080 m from the lens. What is the magnification of the lens?

(a) +3.4
(b) +3.0
(c) +1.7
(d) +0.60
(e) +0.33

Questions 55 through 58 pertain to the statement and diagram below:

The figure is a scaled diagram of an object and a converging lens surrounded by air. Only one focal point, \( F \), of the lens is shown.
55. At which of the labeled points will the image be formed?
   (a) A  (c) C  (e) E
   (b) B  (d) D

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

57. The index of refraction of this lens is 1.51 for red light and 1.53 for blue light. Blue light is focused at the point $F$. Which one of the following statements is true concerning the focal point for red light?
   (a) It is also at $F$.
   (b) It is very close to D.
   (c) It is very close to the lens.
   (d) It is to the left of and close to $F$.
   (e) It is to the right of and close to $F$.

58. The system is immersed in a fluid other than air that has an index of refraction that is larger than that of the lens. Which one of the following statements is true concerning this new situation?
   (a) The image will be real.
   (b) The image will be inverted.
   (c) The image will be enlarged relative to the object.
   (d) The image will be formed on the same side of the lens as the object.
   (e) The lens may act as a diverging lens or a converging lens depending on the location of the object.

Questions 59 through 61 refer to the statement below:

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
   (b) 7.5 cm to the left of the lens
   (c) 7.5 cm to the right of the lens
   (d) 15 cm to the right of the lens
   (e) 30 cm to the right of the lens
63. Determine the height and orientation of the image.
   (a) 2 cm and upright  (d) 8 cm and upright
   (b) 1 cm and inverted  (e) 8 cm and inverted
   (c) 2 cm and inverted

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 a 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 26.9 Lenses in Combination

Questions 68 and 69 pertain to the following statement:

Two converging lenses, each with a focal length of 0.12 m, are used in combination to form an
image of an object located 0.36 m to the left of the left lens in the pair. The distance between
the lenses is 0.24 m.

68. Where is the final image located relative to the lens on the right?
   (a) 0.06 m to the left of the lens  (d) 0.12 m to the right of the lens
   (b) 0.12 m to the left of the lens  (e) 0.36 m to the right of the lens
   (c) 0.18 m to the left of the lens

69. What is the total magnification of this lens combination?
   (a) +1/2  (c) +1  (e) +2
   (b) −1/2  (d) −1
Questions 70 and 71 pertain to the following statement:

A 1.5-cm tall object is placed 0.50 m to the left of a diverging lens with a focal length of 0.20 m. A converging lens with a focal length of 0.17 m is located 0.08 m to the right of the diverging lens.

70. What is the location of the final image with respect to the object?
(a) The final image is located 0.14 m to the left of the object.
(b) The final image is located 0.32 m to the right of the object.
(c) The final image is located 0.40 m to the right of the object.
(d) The final image is located 0.83 m to the right of the object.
(e) The final image is located 1.3 m to the right of the object.

71. What is the height and orientation with respect to the original object of the final image?
(a) 1.4 cm, inverted
(b) 1.4 cm, upright
(c) 0.95 cm, inverted
(d) 0.95 cm, upright
(e) 0.28 cm, inverted

Questions 72 through 74 pertain to the statement and diagram below:

An object is placed 20.0 cm from a converging lens with focal length 15 cm. A concave mirror with focal length 10 cm is located 75 cm to the right of the lens as shown in the figure. Note: The figure is not drawn to scale.

72. Determine the location of the final image.
(a) 48 cm to the right of the lens
(b) 96 cm to the right of the lens
(c) 30 cm to the left of the mirror
(d) 0.225 cm to the left of the mirror
(e) 0.225 cm to the right of the mirror

73. If the height of the object is 1.0 cm, what is the height of the image?
(a) 1.2 cm
(b) 2.4 cm
(c) 6.0 cm
(d) 12 cm
(e) 24 cm

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

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
(b) 20 cm
(c) 45 cm
(d) 60 cm
(e) 75 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. Liu 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  
(b) 2.75 diopters  
(c) 4.00 diopters  
(d) 5.25 diopters  
(e) –5.25 diopters

78. The right lens of Frank'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, Frank's right eye has

(a) a far point of 15.4 cm.  
(b) a far point of 40.0 cm.  
(c) a far point of 66.7 cm.

(d) a near point of 15.4 cm.  
(e) a near 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.  
(b) She has a far point of 0.25 m.  
(c) She has a far point of 3.2 m

(d) She has a near point of 6.4 m.  
(e) She has a near point of 0.87 m.

80. George'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  
(b) 22 cm  
(c) 25 cm  
(d) 75 cm  
(e) 180 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

Section 26.11 Angular Magnification and the Magnifying Glass

83. Which one of the following statements is true concerning a magnifying glass?

(a) It produces a virtual image.  
(b) It produces an inverted image.  
(c) It can be made from a diverging lens.  
(d) The image distance will be less than the object distance.  
(e) The object must be placed outside the focal point of the lens.

84. Mandy is using a magnifying glass ($f = 0.095 \text{ m}$) while trying to solder a computer circuit board. The image is 0.24 m from the lens. What is the distance between the glass and the circuit board?

(a) 0.052 m  
(b) 0.060 m  
(c) 0.068 m  
(d) 0.091 m  
(e) 0.16 m
85. A stamp collector observed his favorite stamp with a magnifying glass with a focal length of 24.0 cm. The image of the stamp was located at his near point distance of 30.0 cm. What was the approximate angular magnification of the magnifying glass when the collector observed his stamp?
(a) 1.00 (c) 1.75 (e) 2.25
(b) 1.25 (d) 2.00

Section 26.12 The Compound Microscope

86. The compound microscope discussed in Cutnell and Johnson's text is made from two lenses. Which one of the following statements is true concerning the operation of this microscope?
(a) Both lenses form real images.
(b) Both lenses form virtual images.
(c) Only the lens closest to the eye forms an image.
(d) The lens closest to the object forms a real image; the other lens forms a virtual image.
(e) The lens closest to the object forms a virtual image; the other lens forms a real image.

87. In her biology class, Chris examines an insect wing under a compound microscope that has an objective lens with a focal length of 0.70 cm, an eyepiece with a focal length of 3.0 cm, and a lens separation distance of 16.00 cm. Chris has a near point distance of 22.5 cm. What is the approximate angular magnification of the microscope as Chris views the insect wing?
(a) $-75$ (c) $-140$ (e) $-250$
(b) $-110$ (d) $-190$

Section 26.13 The Telescope

Section 26.14 Lens Aberrations

88. The moon is observed using a telescope that has an objective lens with a focal length of 3.0 m and an eyepiece with a focal length of 7.5 cm. What is the angular diameter of the moon if the earth-moon distance is $3.85 \times 10^8$ m and the diameter of the moon is $3.48 \times 10^6$ m?
(a) 0.36 rad (c) 9.0 rad (e) 40 rad
(b) 4.7 rad (d) 22 rad

89. Which one of the following statements best explains why chromatic aberration occurs in lenses, but not in mirrors?
(a) The shape of the mirror prevents chromatic aberration.
(b) The thickness of a lens varies from top to bottom.
(c) The frequency of light changes when it passes through glass.
(d) The angle of incidence varies over the surface of a lens for incident parallel rays of light.
(e) Different colors of light are refracted by different amounts as the light passes through a lens.

Additional Problems

90. The length of the wing of an insect is 1 mm. When viewed through a microscope, the image is 1 m long and located 5 m away. Determine the angular magnification if the observer's near point of 25 cm.
(a) 50 (c) 200 (e) 1000
(b) 100 (d) 500

91. A child sitting at the edge of a swimming pool sees a coin resting on the bottom of the pool. The coin appears to be 2.0 ft directly below the water's surface. How deep is the pool at the location of the coin? The index of refraction of water is 1.33.
(a) 1.5 ft (c) 2.7 ft (e) 4.0 ft
(b) 2.0 ft (d) 3.2 ft
92. A physics student desires to create a beam of light that consists of parallel rays. Which one of the following arrangements would allow her to accomplish this task?
(a) A light bulb is placed at the focal point of a convex mirror.
(b) A light bulb is placed at the focal point of a diverging lens.
(c) A light bulb is placed at the focal point of a converging lens.
(d) A light bulb is located at twice the focal length from a concave mirror.
(e) A light bulb is located at twice the focal length from a converging lens.

93. The leg of a spider is 0.2 cm long. When viewed through a microscope, a person with a near point of 25 cm sees an image 2 m long located 10 m away. What is the angular magnification?
(a) 25    (c) 100    (e) 1000
(b) 50    (d) 250

Questions 94 through 97 pertain to the statement and figure below:
The figure shows a point source of unpolarized light at A inside a uniform transparent crystal. The ray \( \text{AO} \) in the crystal strikes the plane surface \( SS' \) making an angle of 30° with the normal. This angle is the critical angle for transmission into air.

94. Determine the index of refraction of the crystal.
(a) 0.58    (c) 1.7    (e) 2.4
(b) 1.2    (d) 2.0

95. If point A is 16 cm below the plane \( SS' \), what is the radius of the largest circle at the air-crystal interface through which light can emerge from the crystal?
(a) 9.2 cm    (c) 18.4 cm    (e) 32.0 cm
(b) 16.0 cm    (d) 27.0 cm

96. For what angle of incidence will the reflected rays of light be completely polarized?
(a) 15°    (c) 30°    (e) 63°
(b) 27°    (d) 60°

97. Which one of the following statements is true concerning this situation?
(a) When the angle of incidence is equal to the Brewster angle, the angle of refraction is 13°.
(b) When the angle of incidence is equal to the Brewster angle, the angle of refraction is 63°.
(c) When the angle of incidence is equal to the Brewster angle, the angle of refraction is 42°.
(d) Since the Brewster angle is less than the critical angle, there is no refraction when the angle of incidence is equal to \( \theta_B \).
(e) Since the Brewster angle is greater than the critical angle, there is no refraction when the angle of incidence is equal to \( \theta_B \).
Questions 98 through 100 pertain to the statement and diagram below:

A fish swims 4.0 m below the surface of a still lake as shown in the figure. When an archer attempts to shoot the fish, the arrow enters the water at point P that is a horizontal distance 1.2 m from the fish.

98. At which of the numbered positions should the archer aim to hit the fish?
   (a) 1
   (b) 2
   (c) 3
   (d) 4
   (e) 5

99. Which one of the following phrases most accurately describes the image of the fish as seen by the archer?
   (a) real and inverted
   (b) virtual and inverted
   (c) real and reversed right to left
   (d) virtual with its orientation unaltered
   (e) real with its orientation unaltered

100. If the archer is successful in shooting the fish, what angle does the arrow make with the horizontal as it enters the water?
    (a) 12°
    (b) 17°
    (c) 23°
    (d) 67°
    (e) 73°

Questions 101 and 102 pertain to the situation described below:

The figure shows a ray of light that originates in an aquarium. It travels through water, is incident on the glass side, and emerges into the air. Ignore any partial reflections.

Note: The figure is not drawn to scale.

101. Which entry in the table below gives the correct values for the angles shown in the figure?

<table>
<thead>
<tr>
<th></th>
<th>α</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>0.55°</td>
<td>2.66°</td>
</tr>
<tr>
<td>b</td>
<td>27.3°</td>
<td>18.4°</td>
</tr>
<tr>
<td>c</td>
<td>27.3°</td>
<td>30.0°</td>
</tr>
<tr>
<td>d</td>
<td>27.3°</td>
<td>41.7°</td>
</tr>
<tr>
<td>e</td>
<td>33.0°</td>
<td>52.2°</td>
</tr>
</tbody>
</table>
102. Which one of the following figures shows the smallest angle of incidence in the water for which no light emerges into air?

Note: *Only one figure is physically possible.*

(a) 

(b) 

(c) 

(d) 

(e)