Physics G12-Q3W4-Revision on light-Qs. Bank

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. Which portion of the electromagnetic spectrum is used in a television?
- a. infrared waves
- b. X rays
- c. radio waves
- d. gamma waves

____ 2. Which portion of the electromagnetic spectrum is used to identify fluorescent minerals?
- a. ultraviolet light
- b. X rays
- c. infrared waves
- d. gamma rays

____ 3. What is the frequency of infrared light of 1.0×10^{-4} m wavelength?
- a. 3.0×10^{-13} Hz
- b. 3.0×10^{2} Hz
- c. 3.0×10^{4} Hz
- d. 3.0×10^{12} Hz

____ 4. What is the frequency of an electromagnetic wave with a wavelength of 1.0×10^{5} m?
- a. 3.3×10^{-4} Hz
- b. 3.0×10^{3} Hz
- c. 1.0×10^{13} Hz
- d. 3.0×10^{13} Hz

____ 5. In a vacuum, electromagnetic radiation of short wavelengths
- a. travels as fast as radiation of long wavelengths.
- b. travels slower than radiation of long wavelengths.
- c. travels faster than radiation of long wavelengths.
- d. can travel both faster and slower than radiation of long wavelengths.

____ 6. The farther light is from a source,
- a. the more spread out light becomes.
- b. the more condensed light becomes.
- c. the more bright light becomes.
- d. the more light is available per unit area.

____ 7. If you are reading a book and you move twice as far away from the light source, how does the brightness at the new distance compare with that at the old distance? It is
- a. one-eighth as bright.
- b. one-fourth as bright.
- c. one-half as bright.
- d. twice as bright.

____ 8. Snow reflects almost all of the light incident upon it. However, a single beam of light is not reflected in the form of parallel rays. This is an example of ____ reflection off a ____ surface.
- a. regular, rough
- b. regular, specular
- c. diffuse, specular
- d. diffuse, rough

____ 9. A highly polished finish on a new car provides a ____ surface for ____ reflection.
- a. rough, diffused
- b. specular, diffused
- c. rough, regular
- d. smooth, specular

____ 10. When a straight line is drawn perpendicular to a flat mirror at the point where an incoming ray strikes the mirror's surface, the angles of incidence and reflection are measured from the normal and
- a. the angles of incidence and reflection are equal.
- b. the angle of incidence is greater than the angle of reflection.
- c. the angle of incidence is less than the angle of reflection.
- d. the angle of incidence can be greater than or less than the angle of reflection.

____ 11. If a light ray strikes a flat mirror at an angle of 14° from the normal, the reflected ray will be
- a. 14° from the mirror's surface.
- c. 90° from the mirror's surface.

b. 76° from the normal.
d. 14° from the normal.

____ 12. If a light ray strikes a flat mirror at an angle of 29° from the normal, the reflected ray will be

a. 29° from the normal.
c. 29° from the mirror's surface.
b. 27° from the normal.
d. 61° from the normal.

____ 13. If a light ray strikes a flat mirror at an angle of 30° from the normal, the ray will be reflected at an angle of

a. 30° from the mirror's surface.
c. 60° from the normal.
b. 60° from the mirror's surface.
d. 90° from the normal.

____ 14. Which of the following best describes the image produced by a flat mirror?

a. virtual, inverted, and magnification greater than one
b. real, inverted, and magnification less than one
c. virtual, upright, and magnification equal to one
d. real, upright, and magnification equal to one

____ 15. When the reflection of an object is seen in a flat mirror, the distance from the mirror to the image depends on

a. the wavelength of light used for viewing.
b. the distance from the object to the mirror.
c. the distance of both the observer and the object to the mirror.
d. the size of the object.

____ 16. What type of mirror is used whenever a magnified image of an object is needed?

a. flat mirror
c. convex mirror
b. concave mirror
d. two-way mirror

____ 17. The mirror equation and ray diagrams are valid concepts only for what type of rays?

a. parallel rays
c. intersecting rays
b. perpendicular rays
d. paraxial rays

____ 18. Object distance, image distance, and radius of curvature are ____ for curved mirrors.

a. interdependent
c. directly related
b. independent
d. unrelated

____ 19. For a spherical mirror, the focal length is equal to ____ the radius of curvature of the mirror.

a. one-fourth
c. one-half
b. one-third
d. the square of

____ 20. A concave mirror with a focal length of 10.0 cm creates a real image 30.0 cm away on its principal axis. How far from the mirror is the corresponding object?

a. 20 cm
c. 7.5 cm
b. 15 cm
d. 5.0 cm

____ 21. A concave mirror forms a real image at 25.0 cm from the mirror surface along the principal axis. If the corresponding object is at a 10.0 cm distance, what is the mirror's focal length?

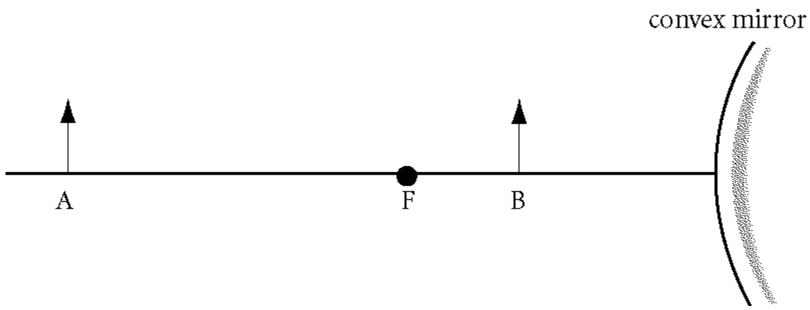
a. 1.40 cm
c. 12.0 cm
b. 7.14 cm
d. 17.0 cm

____ 22. An object is 29 cm away from a concave mirror's surface along the principal axis. If the mirror's focal length is 9.50 cm, how far away is the corresponding image?

a. 12 cm
c. 29 cm
b. 14 cm
d. 36 cm

____ 23. A mirror has an object located on its principal axis 40.0 cm from the mirror's surface. A virtual image is formed 15.0 cm behind the mirror. What is the mirror's focal length?

a. −24.0 cm
c. 2.38 cm
b. −10.9 cm
d. 13 cm



____ 24. In the diagram shown above, the image of object *B* would be
a. real, reduced, and upright.
b. virtual, enlarged, and upright.
c. virtual, reduced, and inverted.
d. virtual, reduced, and upright.

____ 25. Which best describes the image of a concave mirror when the object is located somewhere between the focal point and twice the focal-point distance from the mirror?
a. virtual, upright, and magnification greater than one
b. real, inverted, and magnification less than one
c. virtual, upright, and magnification less than one
d. real, inverted, and magnification greater than one

____ 26. Which best describes the image of a concave mirror when the object is at a distance greater than twice the focal-point distance from the mirror?
a. virtual, upright, and magnification greater than one
b. real, inverted, and magnification less than one
c. virtual, upright, and magnification less than one
d. real, inverted, and magnification greater than one

____ 27. A parabolic mirror, instead of a spherical mirror, can be used to reduce the occurrence of which effect?
a. spherical aberration
b. mirages
c. chromatic aberration
d. light scattering

____ 28. When parallel rays that are also parallel to the principal axis strike a spherical mirror, rays that strike the mirror ____ the principal axis are focused at the focal point. Those rays that strike the mirror ____ the principal axis are focused at points between the mirror and the focal point.
a. perpendicular to, far from
b. close to, perpendicular to
c. close to, far from
d. far from, close to

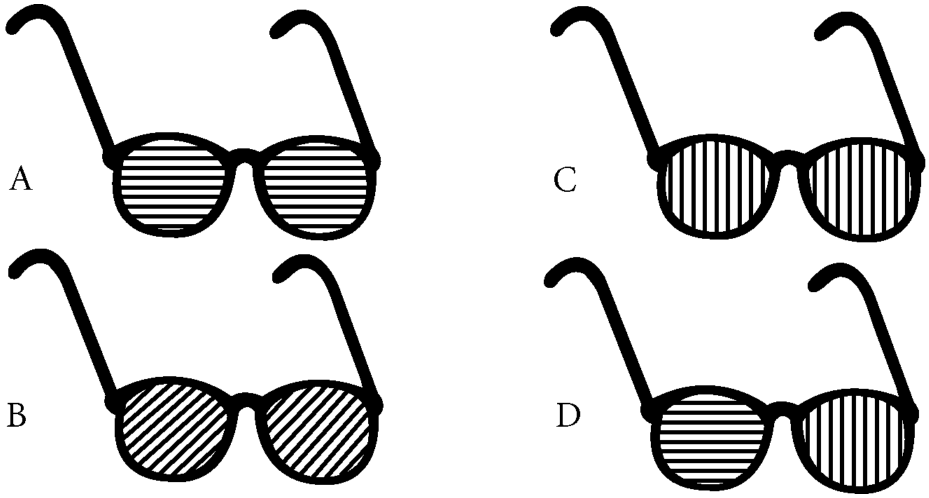
____ 29. When red light and green light shine on the same place on a piece of white paper, the spot appears to be
a. yellow.
b. brown.
c. white.
d. black.

____ 30. Which of the following is *not* an additive primary color?
a. yellow
b. blue
c. red
d. green

____ 31. Which of the following is *not* a primary subtractive color?
a. yellow
b. cyan
c. magenta
d. blue

____ 32. As the angle between the electric-field waves and the transmission axis increases,
a. the component of light that passes through the polarizer decreases and the brightness of the light decreases.
b. the component of light that passes through the polarizer decreases and the brightness of the light increases.
c. the component of light that passes through the polarizer increases and the brightness of the light decreases.

d. the component of light that passes through the polarizer increases and the brightness of the light increases.



____ 33. Which pair of glasses shown above is best suited for automobile drivers? The transmission axes are shown by straight lines on the lenses. (Hint: The light reflects off the hood of the car.)

a. A
b. B
c. C
d. D

____ 34. If you looked at a light through the lenses from two polarizing sunglasses that were overlapped at right angles to each other,

a. all of the light would pass through.
b. most of the light would pass through.
c. little of the light would pass through.
d. none of the light would pass through.

____ 35. Part of a pencil that is placed in a glass of water appears bent in relation to the part of the pencil that extends out of the water. What is this phenomenon called?

a. interference
b. refraction
c. diffraction
d. reflection

____ 36. Refraction is the bending of a wave disturbance as it passes at an angle from one ____ into another.

a. glass
b. medium
c. area
d. boundary

____ 37. The ____ of light can change when light is refracted because the medium changes.

a. frequency
b. medium
c. wavelength
d. transparency

____ 38. Light is *not* refracted when it is

a. traveling from air into a glass of water at an angle of 35° to the normal.
b. traveling from water into air at an angle of 35° to the normal.
c. striking a wood surface at an angle of 75°.
d. traveling from air into a diamond at an angle of 45°.

____ 39. When light passes at an angle to the normal from one material into another material in which its speed is higher,

a. it is bent toward the normal to the surface.
b. it always lies along the normal to the surface.
c. it is unaffected.
d. it is bent away from the normal to the surface.

____ 40. When a light ray moves from air into glass, which has a higher index of refraction, its path is

a. bent toward the normal.
b. bent away from the normal.
c. parallel to the normal.
d. not bent.

____ 41. When a light ray passes from water (n = 1.333) into diamond (n = 2.419) at an angle of 45°, its path is
a. bent toward the normal.
b. bent away from the normal.
c. parallel to the normal.
d. not bent.

____ 42. When a light ray passes from zircon (n = 1.923) into fluorite (n = 1.434) at an angle of 60°, its path is
a. bent toward the normal.
b. bent away from the normal.
c. parallel to the normal.
d. not bent.

____ 43. A ray of light in air is incident on an air-to-glass boundary at an angle of exactly 30.0° with the normal. If the index of refraction of the glass is 1.65, what is the angle of the refracted ray within the glass with respect to the normal?
a. 58.3°
b. 37.3°
c. 34.4°
d. 18.0°

____ 44. A beam of light in air is incident at an angle of 35° to the surface of a rectangular block of clear plastic (n = 1.49). What is the angle of refraction?
a. 12°
b. 23°
c. 42°
d. 57°

____ 45. Carbon tetrachloride (n = 1.46) is poured into a container made of crown glass (n = 1.52). If a light ray in the glass is incident on the glass-to-liquid boundary and makes an angle of 30.0° with the normal, what is the angle of the corresponding refracted ray with respect to the normal?
a. 25.6°
b. 28.7°
c. 31.4°
d. 64.4°

____ 46. What type of image does a converging lens produce?
a. real
b. virtual
c. real or virtual
d. none of the above

____ 47. In what direction does a parallel ray from an object proceed after passing through a diverging lens?
a. The ray passes through the center of curvature, *C*.
b. The ray continues parallel to the principal axis.
c. The ray passes through the center of the lens.
d. The ray is directed away from the focal point, *F*.

____ 48. In what direction does a focal ray from an object proceed after passing through a converging lens?
a. The ray passes through the focal point, *F*.
b. The ray passes through the center of the lens.
c. The ray exits the lens parallel to the principal axis.
d. The ray intersects with the center of curvature, *C*.

____ 49. In what direction does a focal ray from an object proceed after passing through a diverging lens?
a. The ray passes through the focal point, *F*.
b. The ray passes through the center of the lens.
c. The ray exits the lens parallel to the principal axis.
d. The ray intersects with the center of curvature, *C*.

____ 50. In what direction does a parallel ray from an object proceed after passing through a converging lens?
a. The ray passes through the focal point, *F*.
b. The ray continues parallel to the principal axis.
c. The ray passes through the center of the lens.
d. The ray is directed away from the focal point, *F*.

____ 51. All of the following images can be formed by a converging lens *except* which one?
a. virtual, upright, and magnified
b. real and point
c. real, inverted, and magnified
d. real, upright, and magnified

____ 52. All of the following images can be formed by a converging lens *except* which one?
a. image at infinity
b. virtual, inverted, and same size
c. real, inverted, and same size
d. real, inverted, and reduced

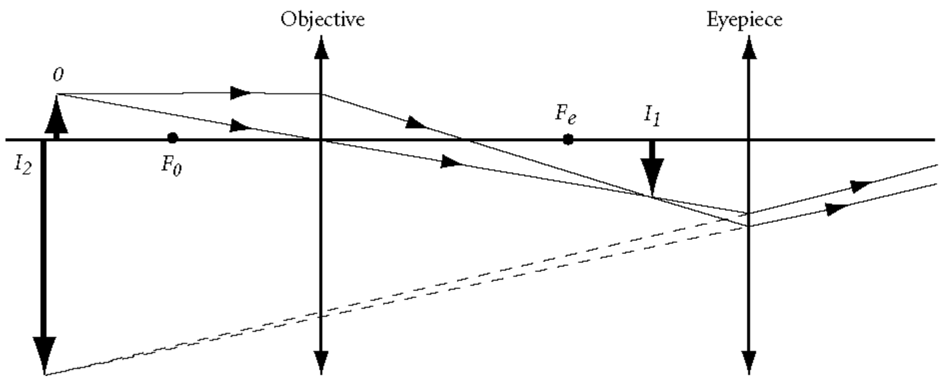
____ 53. How many focal points and focal lengths do converging and diverging lenses have?
a. two, one
b. one, two
c. one, one
d. two, two

____ 54. The focal length for a diverging lens is
a. always positive.
b. always negative.
c. dependent on the location of the object.
d. dependent on the location of the image.

____ 55. An object is placed 14.0 cm from a diverging lens. If a virtual image appears 10.0 cm from the lens on the same side as the object, what is the focal length of the lens?
a. –50 cm
b. –34 cm
c. –5.8 cm
d. –1.6 cm

____ 56. A film projector produces a 1.51 m image of a horse on a screen. If the projector lens is 4.00 m from the screen and the size of the horse on the film is 1.07 cm, what is the magnitude of the magnification of the image?
a. 141
b. 14.1
c. 0.708
d. 7.08×10^{-3}

____ 57. An object that is 18 cm from a converging lens forms a real image 22.5 cm from the lens. What is the magnification of the image?
a. –1.25
b. –0.80
c. 0.80
d. 1.25



____ 58. In the diagram of a compound microscope shown above, where would you place the slide?
a. at *O*
b. at I_2
c. at F_0
d. at I_1

____ 59. Which is *not* correct when describing the formation of rainbows?
a. A rainbow is really spherical in nature.
b. Sunlight is spread into a spectrum when it enters a spherical raindrop.
c. Sunlight is internally reflected on the back side of a raindrop.
d. All wavelengths refract at the same angle.

____ 60. In a double-slit interference experiment, a wave from one slit arrives at a point on a screen one wavelength behind the wave from the other slit. What is observed at that point?
a. dark fringe
c. multicolored fringe

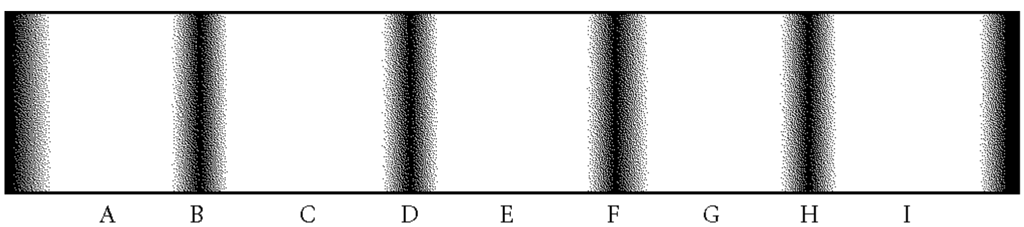
b. bright fringe
d. gray fringe, neither dark nor bright

____ 61. In a double-slit interference experiment, a wave from one slit arrives at a point on a screen one-half wavelength behind the wave from the other slit. What is observed at that point?
a. dark fringe
c. multicolored fringe
b. bright fringe
d. gray fringe, neither dark nor bright

____ 62. In a double-slit interference pattern, the path length from one slit to the first bright fringe of a double-slit interference pattern is longer than the path length from the other slit to the fringe by
a. three-quarters of a wavelength.
c. one-quarter of a wavelength.
b. one-half of a wavelength.
d. one full wavelength.

____ 63. If two lightbulbs are placed side by side, no interference is observed because
a. each bulb produces many wavelengths of light.
b. each bulb produces only one wavelength of light.
c. incandescent light is incoherent.
d. incandescent light is coherent.

____ 64. Coherence is the property by which two waves with identical wavelengths maintain a constant
a. amplitude.
c. phase relationship.
b. frequency.
d. speed.



The figure above shows the pattern of a double-slit interference experiment. The center of the pattern is located at E.

____ 65. In the figure above, which fringe represents a second-order minimum?
a. E
c. G
b. F
d. H

____ 66. In the figure above, 6_1 is the angle between the central maximum and the first-order maximum. What is the angle between fringes D and F?
a. $\frac{\theta_1}{2}$
c. $\frac{3\theta_1}{2}$
b. 6_1
d. 26_1

____ 67. Two beams of coherent light are shining on the same sheet of white paper. When referring to the crests and troughs of such waves, where will darkness appear on the paper?
a. where the crest from one wave overlaps the crest from the other
b. where the crest from one wave overlaps the trough from the other
c. where the troughs from both waves overlap
d. Darkness cannot occur because the two waves are coherent.

____ 68. For stable interference to occur, the phase difference must be
a. incoherent.
c. $\frac{1}{2}\lambda$.
b. monochromatic.
d. constant.

____ 69. The distance between two slits in a double-slit interference experiment is 0.0050 mm. What is the angle of the third-order bright fringe (m = 3) produced with light of 550 nm?

a. 5.0° c. 12°
b. 9.9° d. 19°

____ 70. At the first dark band in a single-slit diffraction pattern, the path lengths of selected pairs of wavelets differ by

a. one wavelength. c. one-half wavelength.
b. more than one wavelength. d. less than half of one wavelength.

____ 71. Monochromatic light shines on the surface of a diffraction grating with 5.3×10^3 lines/cm. The first-order maximum is observed at an angle of 17°. Find the wavelength.

a. 420 nm c. 530 nm
b. 520 nm d. 550 nm

____ 72. Light with a wavelength of 400.0 nm passes through a 1.00×10^4 lines/cm diffraction grating. What is the second-order angle of diffraction?

a. 21.3° c. 56.5°
b. 53.1° d. 72.1°

____ 73. Light with a wavelength of 546.1 nm passes through a 6.62×10^3 lines/cm diffraction grating. What is the first-order angle of diffraction?

a. 21.2° c. 39.2°
b. 34.6° d. 41.6°

____ 74. A helium-neon laser shines monochromatic light (λ = 632.8 nm) perpendicular to the surface of a diffraction grating that contains 146 230 lines/m. Find the angles at which one would observe the second-order and third-order maxima.

a. θ_1 = 5.307°; θ_2 = 10.66° c. θ_1 = 10.66°; θ_2 = 18.43°
b. θ_1 = 10.66°; θ_2 = 16.11° d. θ_1 = 13.25°; θ_2 = 26.50°

____ 75. If light waves are coherent,

a. they shift over time.
b. their intensity is less than that of incoherent light.
c. they remain in phase.
d. they have less than three different wavelengths.

____ 76. In a laser, energy is added to a(n)

a. mirror. c. partially transparent mirror.
b. active medium. d. light wave.

____ 77. Which of the following is the process of using a light wave to produce more waves with properties identical to those of the first wave?

a. stimulated emission c. hologram
b. active medium d. bandwidth

____ 78. Which of the following is a device that produces an intense, nearly parallel beam of coherent light?

a. spectroscope c. laser
b. telescope d. diffraction grating

____ 79. The acronym *laser* stands for light amplification by ____ emission of radiation.

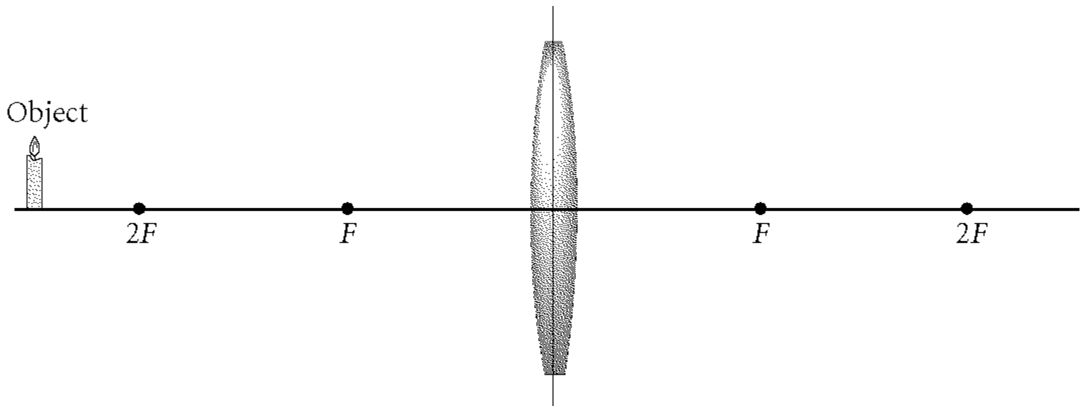
a. similar c. spontaneous
b. simultaneous d. stimulated

____ 80. A laser can be used

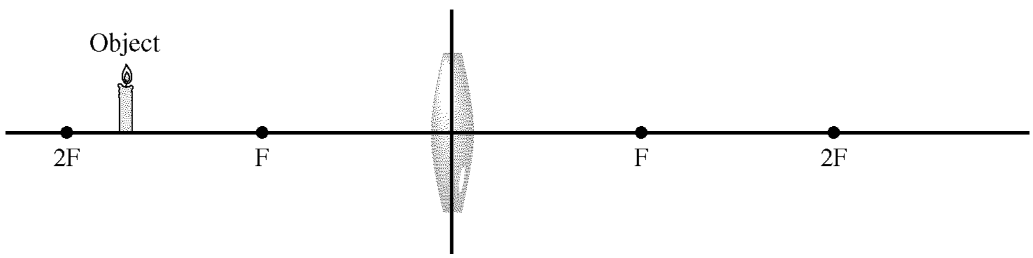
a. to treat glaucoma. c. to read bar codes.
b. to measure distance. d. All of the above

Short Answer

1. If an object or image height is negative, where is the object or image located in relation to the principal axis?
2. What type of image do flat mirrors always form?
3. No refraction occurs when a light ray that is parallel to the normal strikes a transparent medium. Use the wave model of light to explain why.
4. If the angle of incidence is 65.0° and $n_r > n_i$, does a light ray bend toward or away from the normal?



5. What is the position and kind of image produced by the lens shown above? Draw a ray diagram to support your answer.



6. What is the position and kind of image produced by the lens shown above? Draw a ray diagram to support your answer.
7. Why are we able to see the sun in the morning before it actually rises above the horizon?
8. If the number of lines per unit length of a diffraction grating is increased, what happens to the separation of the individual wavelengths of the diffracted light?
9. What is resolving power?
10. What are the advantages of using a “laser knife” in surgical procedures?

Problem

1. Yellow light has a wavelength of 595 nm. What is its frequency?
2. The frequency of an gamma ray is 6.54×10^{18} Hz. What is the gamma ray’s wavelength?

3. A candle 15 cm high is placed in front of a concave mirror at the focal point. The radius of curvature is 60 cm. Draw a ray diagram to determine the position and magnification of the image.
4. An object is 15.0 cm from the surface of a spherical glass tree ornament that is 5.00 cm in diameter. Find the magnification and location of the corresponding image in relation to the mirror's surface. Draw a ray diagram to confirm the position and magnification of the image.
5. A concave spherical mirror has a radius of curvature of 10.0 cm. A candle that is 5.0 cm tall is placed 15.0 cm in front of the mirror. Draw a ray diagram to find the image distance and height. Confirm the results of your diagram with the mirror equation and the equation for magnification.
6. An object is placed along the principal axis of a thin converging lens that has a focal length of 34 cm. If the distance from the image in front of the lens is 59 cm, what is the distance from the object to the lens?
7. A diverging lens has a focal length of 11.2 cm. An insect is placed 9.53 cm in front of the lens. What is the magnification of the image? Describe the image.
8. A converging lens has a focal length of 12.6 cm. If a virtual image of an object is formed 26.8 cm in front of the lens, what is the magnification of the image? Describe the image.
9. An optical fiber is made of a clear plastic (n = 1.35). Light travels through the fiber at angles ranging from 45° to 55°. Predict whether the light will be refracted or whether it will undergo total internal reflection when the cable is in air.
10. A laser placed perpendicular to a diffraction grating that contains 138 566 lines/m illuminates the grating's surface with monochromatic light with a wavelength of 637.3 nm. At what angle will the second-order maximum appear?

Physics G12-Q3W4-Revision on light-Qs. Bank
Answer Section

MULTIPLE CHOICE

1.	ANS: C	PTS: 1	DIF: I	OBJ: 13-1.1
2.	ANS: A	PTS: 1	DIF: I	OBJ: 13-1.1

3. ANS: D

Given

$\lambda = 1.0 \times 10^{-4}$ m

$c = 3.00 \times 10^{8}$ m/s

Solution

Rearrange the wave speed equation, $c = f\lambda$, to isolate f, and calculate.

$$f = \frac{c}{\lambda} = \frac{\left(3.00 \times 10^{8}\ \text{m/s}\right)}{\left(1.0 \times 10^{-4}\ \text{m}\right)} = 3.0 \times 10^{12}\ \text{s}^{-1} = 3.0 \times 10^{12}\ \text{Hz}$$

PTS: 1 DIF: IIIA OBJ: 13-1.2

4. ANS: B

Given

$\lambda = 1.0 \times 10^{5}$ m

$c = 3.00 \times 10^{8}$ m/s

Solution

Rearrange the wave speed equation, $c = f\lambda$, to isolate f, and calculate.

$$f = \frac{c}{\lambda} = \frac{\left(3.00 \times 10^{8}\ \text{m/s}\right)}{\left(1.0 \times 10^{5}\ \text{m}\right)} = 3.0 \times 10^{3}\ \text{s}^{-1} = 3.0 \times 10^{3}\ \text{Hz}$$

PTS: 1 DIF: IIIA OBJ: 13-1.2

5.	ANS: A	PTS: 1	DIF: I	OBJ: 13-1.3
6.	ANS: A	PTS: 1	DIF: I	OBJ: 13-1.4
7.	ANS: B	PTS: 1	DIF: II	OBJ: 13-1.4
8.	ANS: D	PTS: 1	DIF: II	OBJ: 13-2.1
9.	ANS: D	PTS: 1	DIF: I	OBJ: 13-2.1
10.	ANS: A	PTS: 1	DIF: I	OBJ: 13-2.2
11.	ANS: D	PTS: 1	DIF: II	OBJ: 13-2.2
12.	ANS: A	PTS: 1	DIF: II	OBJ: 13-2.2

13. ANS: B

Given

$\theta = 30°$

Solution

According to the law of reflection, $\theta = \theta'$, therefore $\theta' = 30°$. The angle between the reflected ray and the surface is $90° - \theta'$, which equals $60°$. Therefore, the correct response is "B," since the reflected ray forms an angle of $60°$ with the mirror's surface.

PTS: 1 DIF: IIIA OBJ: 13-2.2

14. ANS: C PTS: 1 DIF: I OBJ: 13-2.3
15. ANS: B PTS: 1 DIF: I OBJ: 13-2.3
16. ANS: C PTS: 1 DIF: I OBJ: 13-3.1
17. ANS: D PTS: 1 DIF: I OBJ: 13-3.1
18. ANS: A PTS: 1 DIF: I OBJ: 13-3.1
19. ANS: C PTS: 1 DIF: I OBJ: 13-3.1
20. ANS: B

Given

$f = 10.0 \text{ cm}$

$q = 30.0 \text{ cm}$

Solution

Rearrange the mirror equation, $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$, and solve for p.

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{10.0 \text{ cm}} - \frac{1}{30.0 \text{ cm}} = \frac{3}{30.0 \text{ cm}} - \frac{1}{30.0 \text{ cm}} = \frac{2}{30.0 \text{ cm}}$$

$p = 15 \text{ cm}$

PTS: 1 DIF: IIIB OBJ: 13-3.1

21. ANS: B

Given

$p = 10.0 \text{ cm}$

$q = 25.0 \text{ cm}$

Solution

Use the mirror equation, $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$, and solve for f.

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{10.0 \text{ cm}} + \frac{1}{25.0 \text{ cm}} = \frac{2.5}{25.0 \text{ cm}} + \frac{1}{25.0 \text{ cm}} = \frac{3.5}{25.0 \text{ cm}}$$

$f = 7.14 \text{ cm}$

PTS: 1 DIF: IIIB OBJ: 13-3.1

22. ANS: B

Given

$p = 29$ cm

$f = 9.50$ cm

Solution

Rearrange the mirror equation, $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$, and solve for q.

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{9.50\text{ cm}} - \frac{1}{29\text{ cm}} = \frac{3.05}{29\text{ cm}} - \frac{1}{29\text{ cm}} = \frac{2.05}{29\text{ cm}}$$

$p = 14$ cm

PTS: 1 DIF: IIIB OBJ: 13-3.1

23. ANS: A

Given

$p = 40.0$ cm

$q = -15.0$ cm

Solution

Use the mirror equation, $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$, and solve for f.

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{40.0\text{ cm}} + \frac{1}{-15.0\text{ cm}} = \frac{3.00}{120.\text{ cm}} - \frac{8.00}{120.\text{ cm}} = -\frac{5.00}{120.\text{ cm}}$$

$f = -24.0$ cm

PTS: 1 DIF: IIIB OBJ: 13-3.1

24.	ANS: D	PTS: 1	DIF: II	OBJ: 13-3.3
25.	ANS: D	PTS: 1	DIF: II	OBJ: 13-3.3
26.	ANS: B	PTS: 1	DIF: II	OBJ: 13-3.3
27.	ANS: A	PTS: 1	DIF: I	OBJ: 13-3.4
28.	ANS: C	PTS: 1	DIF: II	OBJ: 13-3.4
29.	ANS: A	PTS: 1	DIF: I	OBJ: 13-4.1
30.	ANS: A	PTS: 1	DIF: I	OBJ: 13-4.1
31.	ANS: D	PTS: 1	DIF: I	OBJ: 13-4.2
32.	ANS: A	PTS: 1	DIF: II	OBJ: 13-4.3
33.	ANS: C	PTS: 1	DIF: II	OBJ: 13-4.3
34.	ANS: D	PTS: 1	DIF: II	OBJ: 13-4.3
35.	ANS: B	PTS: 1	DIF: I	OBJ: 14-1.1
36.	ANS: B	PTS: 1	DIF: I	OBJ: 14-1.1
37.	ANS: C	PTS: 1	DIF: I	OBJ: 14-1.1
38.	ANS: C	PTS: 1	DIF: I	OBJ: 14-1.1
39.	ANS: D	PTS: 1	DIF: I	OBJ: 14-1.2
40.	ANS: A	PTS: 1	DIF: II	OBJ: 14-1.2
41.	ANS: A	PTS: 1	DIF: II	OBJ: 14-1.2

42. ANS: B PTS: 1 DIF: II OBJ: 14-1.2

43. ANS: D

Given

$\theta_i = 30.0°$

$n_i = 1.00$

$n_r = 1.65$

Solution

Rearrange Snell's law, $n_i \sin\theta_i = n_r \sin\theta_r$, and solve for θ_r.

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{1.00}{1.65}\left(\sin 3.0 \times 10^{1}°\right)\right] = 18.0°$$

PTS: 1 DIF: IIIA OBJ: 14-1.3

44. ANS: B

Given

$\theta_i = 35°$

$n_i = 1.00$

$n_r = 1.49$

Solution

Rearrange Snell's law, $n_i \sin\theta_i = n_r \sin\theta_r$, and solve for θ_r.

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{1.00}{1.49}\left(\sin 35°\right)\right] = 23°$$

PTS: 1 DIF: IIIA OBJ: 14-1.3

45. ANS: C

Given

$\theta_i = 30.0°$

$n_i = 1.52$

$n_r = 1.46$

Solution

Rearrange Snell's law, $n_i \sin\theta_i = n_r \sin\theta_r$, and solve for θ_r.

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{1.52}{1.46}\left(\sin 30.0°\right)\right] = 31.4°$$

PTS: 1 DIF: IIIB OBJ: 14-1.3

46. ANS: C PTS: 1 DIF: I OBJ: 14-2.1

47. ANS: D PTS: 1 DIF: I OBJ: 14-2.1

48. ANS: C PTS: 1 DIF: I OBJ: 14-2.1

49. ANS: C PTS: 1 DIF: I OBJ: 14-2.1

50. ANS: A PTS: 1 DIF: I OBJ: 14-2.1

51. ANS: D	PTS: 1	DIF: II	OBJ: 14-2.1
52. ANS: B	PTS: 1	DIF: II	OBJ: 14-2.1
53. ANS: A	PTS: 1	DIF: I	OBJ: 14-2.1
54. ANS: B	PTS: 1	DIF: I	OBJ: 14-2.2

55. ANS: B

Given

$p = 14.0$ cm

$q = -10.0$ cm (q is negative, since the image is virtual and in front of the lens)

Solution

Use the thin-lens equation to find f.

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{14.0 \text{ cm}} + \frac{1}{-10.0 \text{ cm}} = \frac{0.0714}{1 \text{ cm}} - \frac{0.100}{1 \text{ cm}} = -\frac{0.029}{1 \text{ cm}}$$

$f = -34$ cm

PTS: 1 DIF: IIIA OBJ: 14-2.2

56. ANS: A

Given

$h' = 1.51$ m $= 151$ cm

$p = 4.00$ m

$h = 1.07$ cm

Solution

Use the magnification of a lens equation, $M = \frac{h'}{h}$, to find M.

$$M = \frac{h'}{h} = \frac{(151 \text{ cm})}{(1.07 \text{ cm})} = 141$$

PTS: 1 DIF: IIIA OBJ: 14-2.3

57. ANS: A

Given

$p = 18.0$ cm

$q = 22.5$ cm (q is positive, since the image is real)

Solution

Use the magnification of a lens equation, $M = -\frac{q}{p}$, to find M.

$$M = -\frac{q}{p} = -\frac{(22.5 \text{ cm})}{(18.0 \text{ cm})} = -1.25$$ (since M is negative, a real, inverted image is formed)

PTS: 1 DIF: IIIA OBJ: 14-2.3

58. ANS: A	PTS: 1	DIF: I	OBJ: 14-2.4
59. ANS: D	PTS: 1	DIF: I	OBJ: 14-3.3

60.	ANS:	B	PTS:	1	DIF:	I	OBJ:	15-1.1
61.	ANS:	A	PTS:	1	DIF:	I	OBJ:	15-1.1
62.	ANS:	D	PTS:	1	DIF:	I	OBJ:	15-1.1
63.	ANS:	C	PTS:	1	DIF:	I	OBJ:	15-1.1
64.	ANS:	C	PTS:	1	DIF:	I	OBJ:	15-1.1
65.	ANS:	D	PTS:	1	DIF:	I	OBJ:	15-1.2
66.	ANS:	B	PTS:	1	DIF:	II	OBJ:	15-1.2
67.	ANS:	B	PTS:	1	DIF:	I	OBJ:	15-1.2
68.	ANS:	D	PTS:	1	DIF:	II	OBJ:	15-1.2

69. ANS: D

Given

$d = 0.0050 \text{ mm} = 5.0 \times 10^{-6} \text{ m}$

$m = 3$

$\lambda = 550 \text{ nm} = 5.5 \times 10^{-6} \text{ m}$

Solution

$d \sin\theta = m\lambda$

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{(3)(5.5 \times 10^{-7} \text{ m})}{(5.0 \times 10^{-6} \text{ m})}\right) = 19°$$

PTS: 1 DIF: IIIB OBJ: 15-1.3

70. ANS: C PTS: 1 DIF: II OBJ: 15-2.1

71. ANS: D

Given

$$d = \frac{1}{5.3 \times 10^{3} \frac{\text{lines}}{\text{cm}}} = \frac{1}{5.3 \times 10^{3}} \text{ cm}$$

$m = 1$

$\theta = 17°$

Solution

$d \sin\theta = m\lambda$

$$\lambda = \frac{d \sin\theta}{m} = \frac{\left(\frac{1}{5.3 \times 10^{3}} \text{ cm}\right)(\sin 17°)}{1} = 5.5 \times 10^{-5} \text{ cm} = 5.5 \times 10^{2} \text{ nm}$$

PTS: 1 DIF: IIIA OBJ: 15-2.2

72. ANS: B

Given

$$d = \frac{1}{1.0 \times 10^{4} \frac{\text{lines}}{\text{cm}}} = \frac{1}{1.0 \times 10^{4}} \text{ cm} = \frac{1}{1.0 \times 10^{4}} \text{ cm}\left(\frac{1 \text{ m}}{100 \text{ cm}}\right) = \frac{1}{1.0 \times 10^{6}} \text{ m}$$

$m = 2$

$\lambda = 400.0 \text{ nm} = 4.000 \times 10^{-7} \text{ m}$

Solution

$d \sin\theta = m\lambda$

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{(2)(4.000 \times 10^{-7}\ \text{m})}{\left(\frac{1}{1.00 \times 10^{-6}}\ \text{m}\right)}\right) = 53.1°$$

PTS: 1 DIF: IIIB OBJ: 15-2.2

73. ANS: A

Given

$$d = \frac{1}{6.62 \times 10^{3}\ \frac{\text{lines}}{\text{cm}}} = \frac{1}{6.62 \times 10^{3}}\ \text{cm}\left(\frac{1\ \text{m}}{100\ \text{cm}}\right) = \frac{1}{6.62 \times 10^{5}}\ \text{m}$$

$m = 1$

$\lambda = 546.1\ \text{nm} = 5.461 \times 10^{-7}\ \text{m}$

Solution

$d \sin\theta = m\lambda$

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{(5.461 \times 10^{-7}\ \text{m})}{\left(\frac{1}{6.62 \times 10^{5}}\ \text{m}\right)}\right) = 21.2°$$

PTS: 1 DIF: IIIB OBJ: 15-2.2

74. ANS: B

Given

$\lambda = 632.8\ \text{nm} = 6.328 \times 10^{-7}\ \text{m}$

$$d = \frac{1}{1.462\ 30 \times 10^{5}\ \frac{\text{lines}}{\text{m}}} = \frac{1}{1.462\ 30 \times 10^{5}}\ \text{m}$$

$m = 2, 3$

Solution

$d \sin\theta = m\lambda$

$$\theta_1 = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{(2)(6.328 \times 10^{-7}\ \text{m})}{\left(\frac{1}{1.462\ 30 \times 10^{5}}\ \text{m}\right)}\right) = 10.66°$$

$$\theta_2 = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{(3)(6.328 \times 10^{-7}\ \text{m})}{\left(\frac{1}{1.462\ 30 \times 10^{5}}\ \text{m}\right)}\right) = 16.11°$$

PTS: 1 DIF: IIIC OBJ: 15-2.2

75. ANS: C PTS: 1 DIF: I OBJ: 15-3.1
76. ANS: B PTS: 1 DIF: I OBJ: 15-3.1
77. ANS: A PTS: 1 DIF: I OBJ: 15-3.1
78. ANS: C PTS: 1 DIF: I OBJ: 15-3.1
79. ANS: D PTS: 1 DIF: I OBJ: 15-3.1
80. ANS: D PTS: 1 DIF: I OBJ: 15-3.2

SHORT ANSWER

1. ANS:
below the principal axis

PTS: 1 DIF: I OBJ: 13-3.1

2. ANS:
virtual

PTS: 1 DIF: I OBJ: 13-3.3

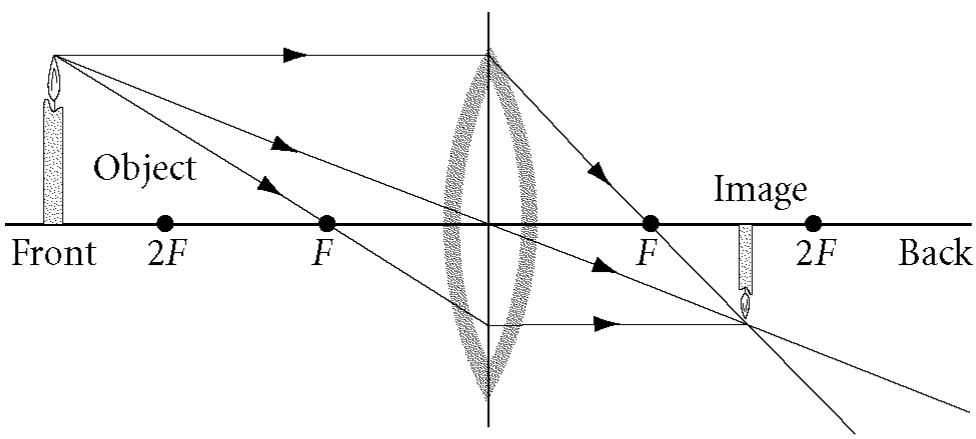
3. ANS:
A light ray represents the direction of propagation of a planar wave front, which is the superposition of all the spherical wave fronts. As these wave fronts enter a transparent medium, all of them strike the surface simultaneously and experience a similar change in velocity at the same instant. Although this results in a change in the overall wavelength of the spherical wave fronts, there is no change in the direction of the wave fronts relative to each other. Therefore, no refraction occurs.

PTS: 1 DIF: II OBJ: 14-1.2

4. ANS:
toward the normal

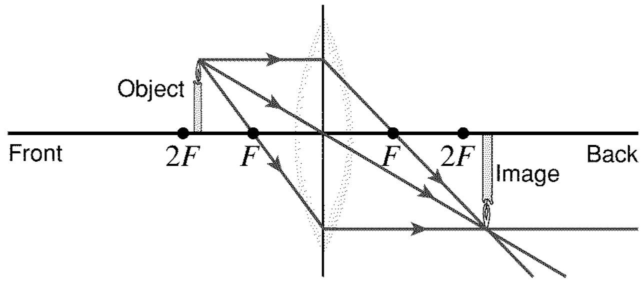
PTS: 1 DIF: I OBJ: 14-1.2

5. ANS:
A real, inverted image that is smaller than the object will form between *F* and 2*F*.



PTS: 1 DIF: II OBJ: 14-2.1

6. ANS:
A real, inverted image that is larger than the object will form outside 2*F*.



PTS: 1 DIF: II OBJ: 14-2.1

7. ANS:
Rays of light from the sun strike Earth's atmosphere and are bent because the atmosphere has an index of refraction greater than that of the near-vacuum of space.

PTS: 1 DIF: II OBJ: 14-3.2

8. ANS:
The separation of the individual wavelengths of the diffracted light is increased.

PTS: 1 DIF: II OBJ: 15-2.2

9. ANS:
Resolving power is the ability of an optical instrument to separate two images that are close together.

PTS: 1 DIF: I OBJ: 15-2.3

10. ANS:
A "laser knife" cuts through tissue like a steel scalpel; however, the energy from the laser coagulates blood, sealing the blood vessels and preventing blood loss and infection.

PTS: 1 DIF: II OBJ: 15-3.2

PROBLEM

1. ANS:
5.04×10^{14} Hz

Given

$\lambda = 595 \text{ nm} = 595 \times 10^{-9} \text{ m} = 5.95 \times 10^{-7} \text{ m}$

$c = 3.00 \times 10^{8} \text{ m/s}$

Solution

Rearrange the wave speed equation, $c = f\lambda$, to isolate f, and calculate.

$$f = \frac{c}{\lambda} = \frac{\left(3.00 \times 10^{8} \text{ m/s}\right)}{\left(5.95 \times 10^{-7} \text{ m}\right)} = 5.04 \times 10^{14} \text{ s}^{-1} = 5.04 \times 10^{14} \text{ Hz}$$

PTS: 1 DIF: IIIA OBJ: 13-1.2

2. ANS:

4.59×10^{-11} m

Given

$f = 6.54 \times 10^{18}$ Hz $= 6.54 \times 10^{18}$ s^{-1}

$c = 3.00 \times 10^{8}$ m/s

Solution

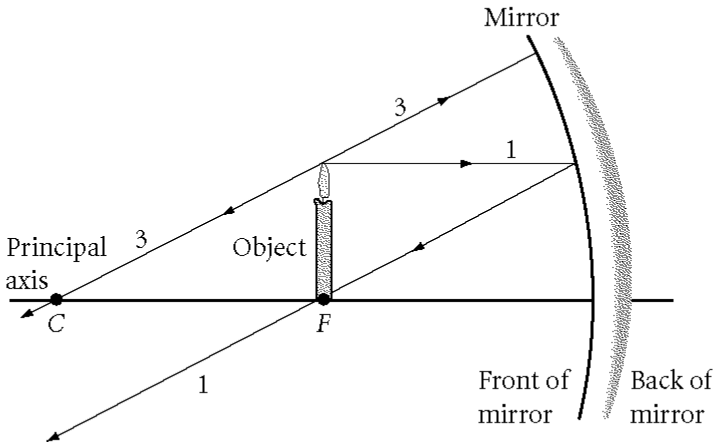
Rearrange the wave speed equation, $c = f\lambda$, to isolate λ, and calculate.

$$\lambda = \frac{c}{f} = \frac{\left(3.00 \times 10^{8}\ \text{m/s}\right)}{\left(6.54 \times 10^{18}\ \text{s}^{-1}\right)} = 4.59 \times 10^{-11}\ \text{m}$$

PTS: 1 DIF: IIIA OBJ: 13-1.2

3. ANS:

When the candle is at the focal point, the image is infinitely far to the left and therefore is not seen, as shown in the answer diagram.

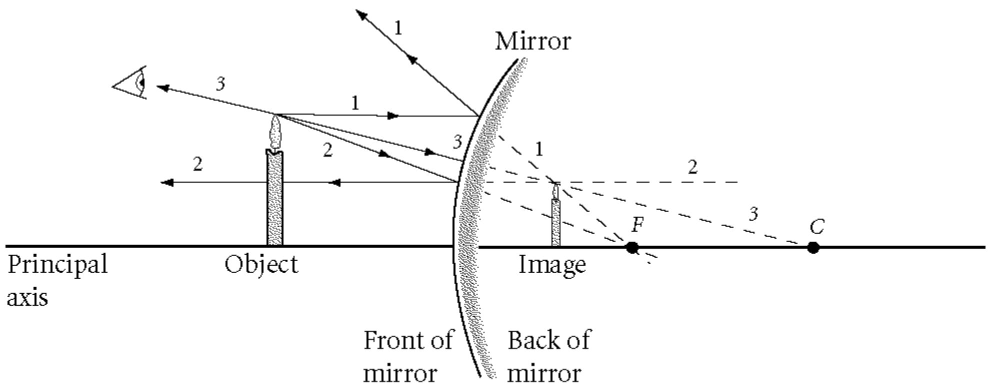


PTS: 1 DIF: IIIB OBJ: 13-3.2

4. ANS:

$q = -1.15$ cm

$M = +7.69 \times 10^{-2}$



Given

$d = 5.00$ cm

$p = 15.0$ cm

Solution

Since $d = 5.00$ cm, $R = 2.50$ cm.

Since the ornament acts like a convex mirror, $f = -1.25$ cm.

Rearrange the mirror equation, $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$, and solve for q.

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-1.25 \text{ cm}} - \frac{1}{15.0 \text{ cm}} = -\frac{12}{15.0 \text{ cm}} - \frac{1}{15.0 \text{ cm}} = -\frac{13}{15.0 \text{ cm}}$$

$q = -1.15$ cm

Since q is negative, the image is located 1.15 cm behind the mirror (or inside the ornament).

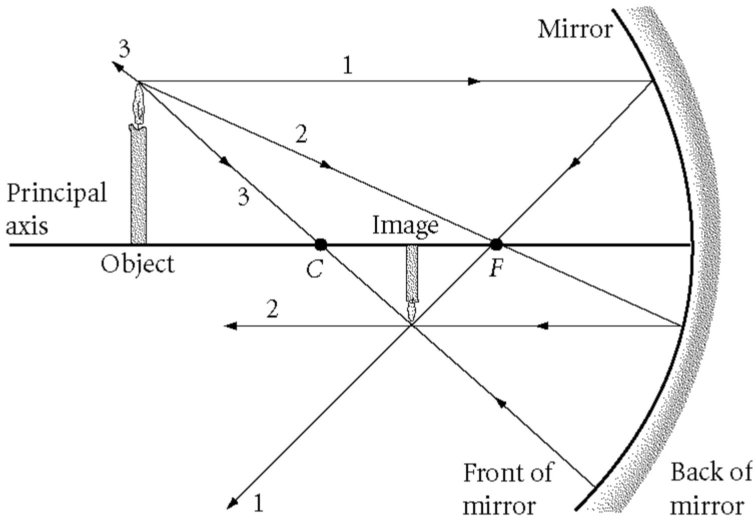
$$M = -\frac{q}{p} = -\frac{(-1.15 \text{ cm})}{15.0 \text{ cm}} = +7.69 \times 10^{-2}$$

PTS: 1 DIF: IIIC OBJ: 13-3.1

5. ANS:

$q = 7.50$ cm

$h' = -2.5$ cm



Given

$h = 5.0$ cm

$R = 10.0$ cm

$p = 15.0$ cm

Solution

Since $R = 10.0$ cm, $f = 5.00$ cm.

Rearrange the mirror equation, $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$, and solve for q.

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{5.00\text{ cm}} - \frac{1}{15.0\text{ cm}} = \frac{3}{15.0\text{ cm}} - \frac{1}{15.0\text{ cm}} = \frac{2}{15.0\text{ cm}}$$

$q = 7.50$ cm

Since q is positive, the image is located 7.50 cm in front of the mirror.

Solve the equation for magnification, $M = \frac{h'}{h} = -\frac{q}{p}$, for h'.

$$h' = -\frac{qh}{p} = -\frac{(7.50\text{ cm})(5.0\text{ cm})}{(15.0\text{ cm})} = -2.5\text{ cm}$$

Since h' is negative, the image is located below the principal axis.

PTS: 1 DIF: IIIC OBJ: 13-3.2

6. ANS:
22 cm

Given

$q = -59$ cm ($q < 0$ for an image in front of the lens)

$f = 34$ cm ($f > 0$ for a converging lens)

Solution

Rearrange the thin-lens equation, $\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$, and solve for p.

$$\frac{1}{p}=\frac{1}{f}-\frac{1}{q}=\frac{1}{34\text{ cm}}-\frac{1}{-59\text{ cm}}=\frac{0.029}{1\text{ cm}}+\frac{0.017}{1\text{ cm}}=\frac{0.046}{1\text{ cm}}$$

$p = 22$ cm ($p > 0$, so the object is in front of the lens)

PTS: 1 DIF: IIIB OBJ: 14-2.2

7. ANS:
0.540; The image is smaller than the object. $M > 0$, so the image is virtual and upright.

Given

$p = 9.53$ cm ($p > 0$ for an object in front of the lens)

$f = -11.2$ cm ($f < 0$ for a diverging lens)

Solution

First, rearrange the thin-lens equation, $\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$, to find q.

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{-9.53\text{ cm}}-\frac{1}{11.2\text{ cm}}=-\frac{0.105}{1\text{ cm}}-\frac{0.0893}{1\text{ cm}}=-\frac{0.194}{1\text{ cm}}$$

$q = -5.15$ cm (since q is negative, the image is virtual)

Use the magnification of a lens equation, $M=-\frac{q}{p}$, to find M.

$$M=-\frac{q}{p}=-\frac{(-5.15\text{ cm})}{(9.53\text{ cm})}=0.540$$

The image is smaller than the object. $M > 0$, so the image is virtual and upright.

PTS: 1 DIF: IIIB OBJ: 14-2.3

8. ANS:
3.13; The image is three and a half times larger than the object. $M > 0$, so the image is virtual and upright.

Given

$f = 12.6$ cm ($f > 0$ for a converging lens)

$q = -26.8$ cm ($q < 0$ for an image in front of the lens)

Solution

First, rearrange the thin-lens equation, $\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$, to find p.

$$\frac{1}{p}=\frac{1}{f}-\frac{1}{q}=\frac{1}{12.6\text{ cm}}-\frac{1}{-26.8\text{ cm}}=\frac{0.0794}{1\text{ cm}}+\frac{0.0373}{1\text{ cm}}=\frac{0.1167}{1\text{ cm}}$$

$p = 8.569$ cm

Use the magnification of a lens equation, $M=-\frac{q}{p}$, to find M.

$$M=-\frac{q}{p}=-\frac{(-26.8\text{ cm})}{(8.569\text{ cm})}=3.13$$

The image is three and a half times larger than the object. $M > 0$, so the image is virtual and upright.

PTS: 1 DIF: IIIC OBJ: 14-2.3

9. ANS:
When the angle of incidence is greater than the critical angle, the light ray will undergo total internal reflection. Because the angle of incidence for the light rays ranges from 45° to 55°, some of the rays will undergo total internal reflection. Light rays whose angle of incidence is less than 47.8° will refract.

Given

$n_{optic\ cable} = 1.35$

$n_{air} = 1.00$

$\theta_i = 45° - 55°$

Solution

Rearrange the critical angle equation, $\sin\theta_c=\frac{n_r}{n_i}$, to find θ_c.

$$\theta_c=\sin^{-1}\left(\frac{n_r}{n_i}\right)=\sin^{-1}\left(\frac{n_{air}}{n_{optic\ cable}}\right)=\sin^{-1}\left(\frac{1.00}{1.35}\right)=\sin^{-1}(0.741)=47.8°$$

When the angle of incidence is greater than the critical angle, the light ray will undergo total internal reflection. Because the angle of incidence for the light rays ranges from 45° to 55°, some of the rays will undergo total internal reflection. Light rays whose angle of incidence is less than 47.8° will refract.

PTS: 1 DIF: IIIB OBJ: 14-3.1

10. ANS:
$\theta = 10.17°$

Given

$\lambda = 637.3\text{ nm} = 6.373\times10^{-7}\text{ m}$

$$d=\frac{1}{1.38566\times10^5\ \frac{\text{lines}}{\text{m}}}=\frac{1}{1.38566\times10^5}\text{ m}$$

$m = 2$

Solution

$d \sin\theta = m\lambda$

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right) = \sin^{-1}\left(\frac{(2)(6.373 \times 10^{-7}\text{ m})}{\left(\frac{1}{1.38566 \times 10^{5}}\text{ m}\right)}\right) = \sin^{-1}\left((2)(6.373 \times 10^{-7}\text{ m})\left(1.38566 \times 10^{5}\right)\right)$$

$$\theta = \sin^{-1}(0.1766) = 10.17°$$

PTS: 1 DIF: IIIB OBJ: 15-2.2