Name: _____ **Class:** _____ **Date:** _____ **ID: A**

AP B mirrors and lenses websheet 23.2

Multiple Choice

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

____ 1. The ____ of light can change when light is refracted because the medium changes.
a. frequency
b. medium
c. wavelength
d. transparency

____ 2. When light passes at an angle to the normal from one material into another material in which its speed is lower,
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.

____ 3. 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.

____ 4. 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.

____ 5. 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°

____ 6. What type of image is formed when rays of light actually intersect?
a. real
b. virtual
c. curved
d. projected

____ 7. What type of image does a converging lens produce?
a. real
b. virtual
c. real or virtual
d. none of the above

____ 8. 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*.

____ 9. 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

____ 10. 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

____ 11. 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

____ 12. The focal length for a converging lens is
a. always positive.
b. always negative.
c. dependent on the location of the object.
d. dependent on the location of the image.

____ 13. A virtual image has a ____ image distance (q) and is located in ____ of the lens.
a. positive, front
b. positive, back
c. negative, front
d. negative, back

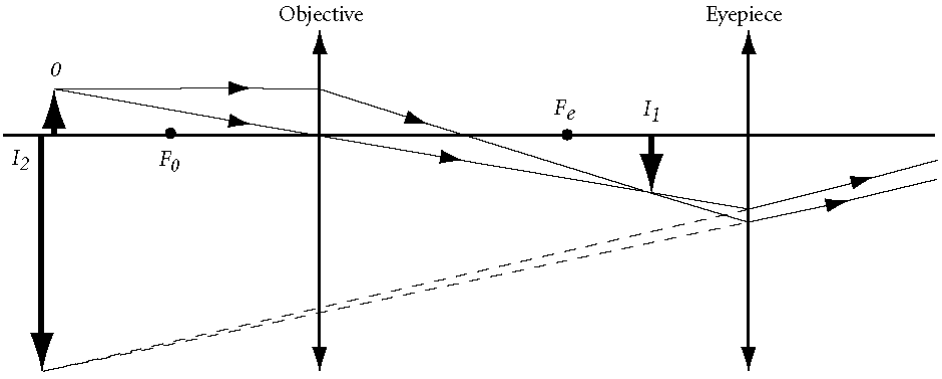
____ 14. The focal length for a diverging lens is
a. always positive.
b. always negative.
c. dependent on the location of the object.
d. dependent on the location of the image.

____ 15. An object is placed 20.0 cm from a thin converging lens along the axis of the lens. If a real image forms behind the lens at a distance of 8.00 cm from the lens, what is the focal length of the lens?
a. 5.71 cm
b. 12.0 cm
c. –13.3 cm
d. 13.3 cm

____ 16. 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

____ 17. 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}

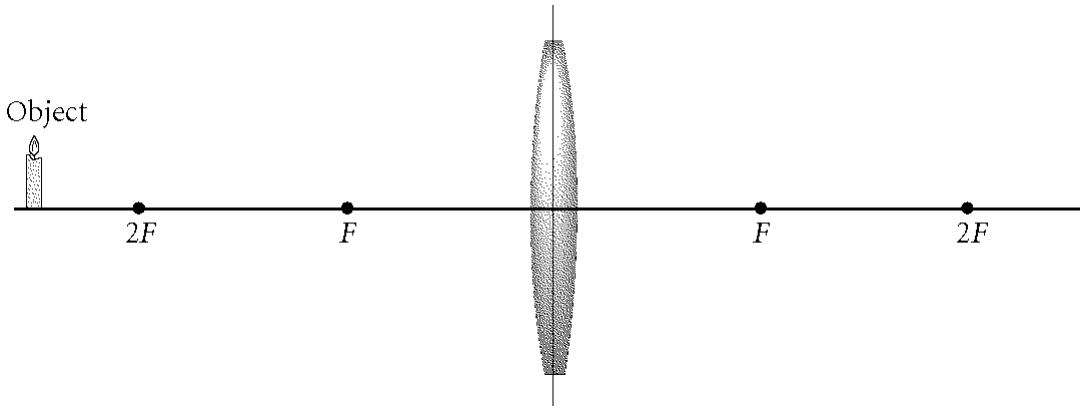
____ 18. An object that is 18 cm from a converging lens forms a real image 22.5 cm from the lens. What is the magnification of the image?
a. –1.25
b. –0.80
c. 0.80
d. 1.25



____ 19. 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

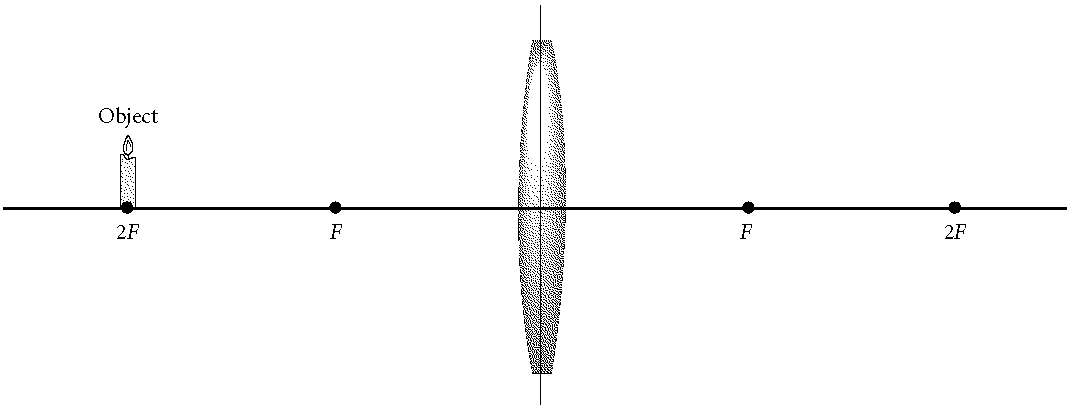
____ 20. Which is *not* correct when describing the formation of rainbows?
a. A rainbow is really spherical in nature.
b. Sunlight is spread into a spectrum when it enters a spherical raindrop.
c. Sunlight is internally reflected on the back side of a raindrop.
d. All wavelengths refract at the same angle.

Short Answer

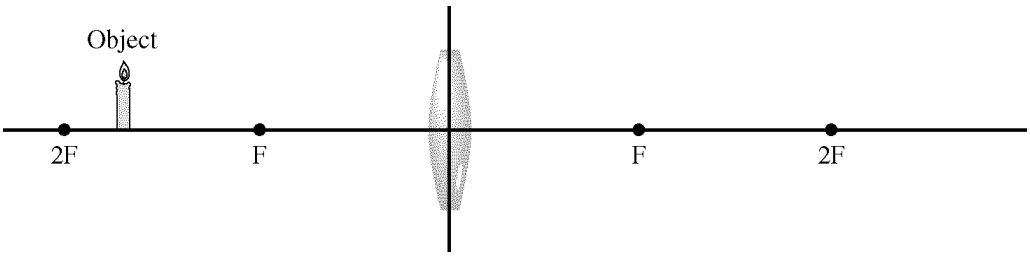


21. What is the position and kind of image produced by the lens shown above? Draw a ray diagram to support your answer.

22. A student burns a hole in a pencil with a magnifying lens. What is the position and kind of image produced by the lens? Draw a ray diagram to support your answer.



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



24. What is the position and kind of image produced by the lens shown above? Draw a ray diagram to support your answer.
25. Under what conditions is the thin-lens equation applicable for determining object distance, image distance, and focal length?
26. A real image has a(n) _____ image distance (p) and is located in _____ of the lens.
27. An object is placed 40.0 cm from a converging lens along the axis of the lens. If a virtual image forms at a distance of 50.0 cm from the lens on the same side as the object, what is the focal length of the lens?
28. What does a positive magnification signify?
29. What does the perceived color of each water droplet in a rainbow depend on?

Problem

30. A ray of light passes from air into carbon disulfide (n = 1.63) at an angle of 28.0° to the normal. What is the refracted angle?
31. A ray of light passes from air into cubic zirconia at an angle of 56.0° to the normal. The angle of refraction is 22.0°. What is the index of refraction of cubic zirconia?
32. A ray of light passes from air into ice (n = 1.309) at an angle of 46.0° to the normal. The refracted ray of light then passes from ice into glycerine (n = 1.473). What is the angle of refraction of the ray of light in glycerine?
33. A ray of light passes from air into carbon disulfide (n = 1.628) at an angle of 55.0° to the normal. The refracted ray of light then passes from carbon disulfide into water (n = 1.333). What is the refracted angle in the water?
34. A converging lens has a focal length of 10.0 cm. If a virtual image of an object is formed 25.0 cm in front of the lens, what is the magnification of the image? Describe the image.
35. A candle that is 10.0 cm high is placed 30.0 cm in front of a diverging lens. The lens has a focal length of 20.0 cm. What is the height of the image?
36. A ray of light travels across a liquid-to-glass interface. The index of refraction is 1.75 for the liquid and 1.52 for the glass. If the light meets the interface at an angle of 59°, predict whether the light will refract or whether it will undergo total internal reflection.

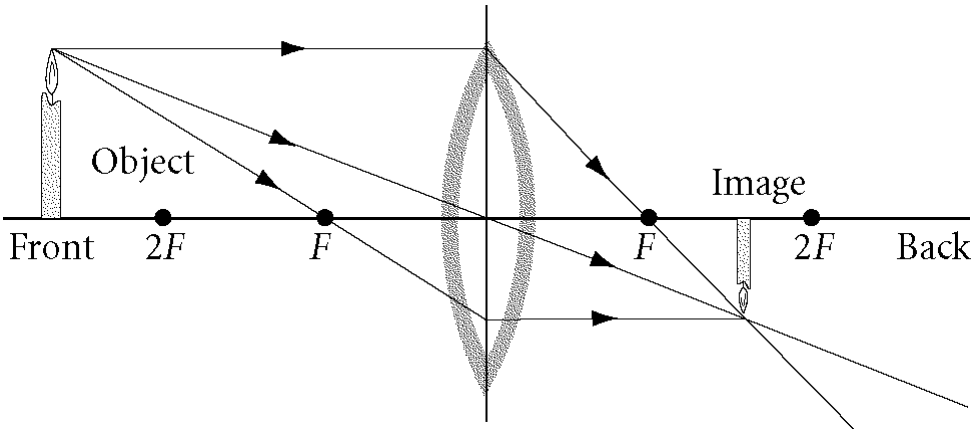
AP B mirrors and lenses websheet 23.2
Answer Section

MULTIPLE CHOICE

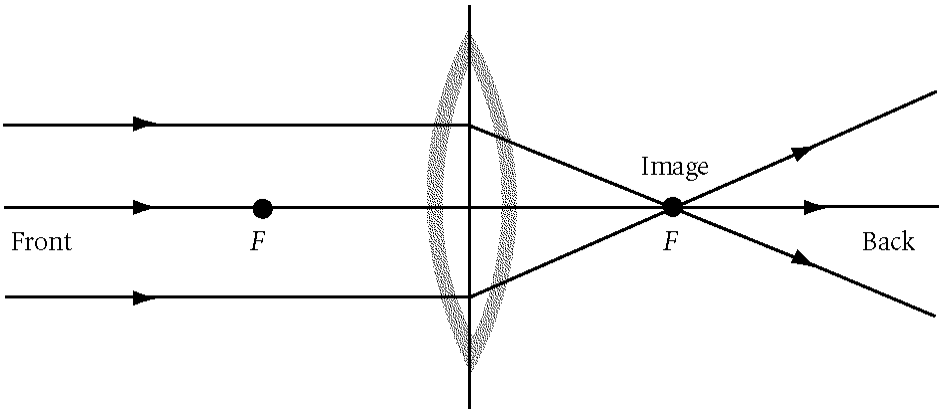
1. C
2. A
3. A
4. B
5. D
6. A
7. C
8. D
9. D
10. B
11. A
12. A
13. C
14. B
15. A
16. B
17. A
18. A
19. A
20. D

SHORT ANSWER

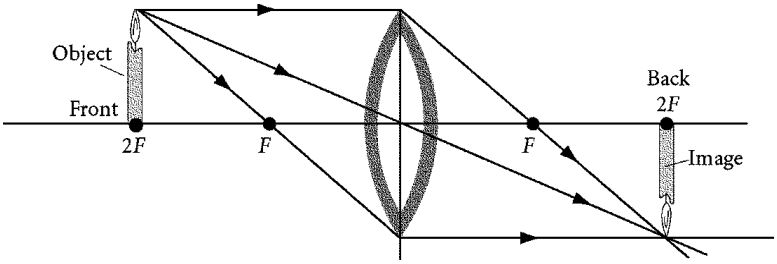
21. A real, inverted image that is smaller than the object will form between *F* and 2*F*.



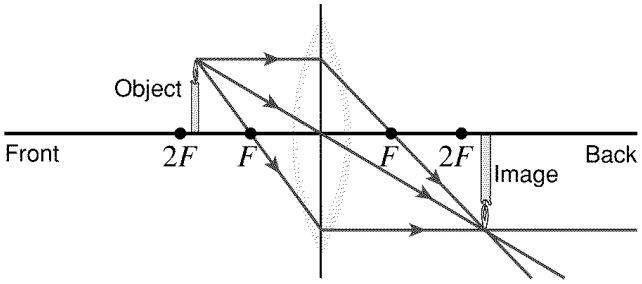
22. A real, point image will form at F.



23. A real, inverted image that is the same size as the object will form at $2F$.



24. A real, inverted image that is larger than the object will form outside $2F$.



25. when the lens thickness is much smaller than the focal length
26. positive, back
27. *Given*

$p = 40.0\ \text{cm}$

$q = -50.0\ \text{cm}$ (q is negative, since the image is virtual and in front of the lens)

Solution

Use the thin-lens equation to find f.

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{40.0\ \text{cm}} + \frac{1}{-50.0\ \text{cm}} = \frac{0.0250}{1\ \text{cm}} - \frac{0.0200}{1\ \text{cm}} = \frac{0.0050}{1\ \text{cm}}$$

$f = 2.0 \times 10^2\ \text{cm}$ (positive focal length is consistent with a converging lens)

28. The image is upright and virtual.
29. The perceived color depends on the angle at which that drop is viewed.

PROBLEM

30. 16.7°

Given
$\theta_i = 28.0°$

$n_i = 1.00$

$n_r = 1.63$

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

$$\theta_r = \sin^{-1}\left[\frac{n_i}{n_r}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{1.00}{1.63}\left(\sin 28.0°\right)\right] = 16.7°$$

31. 2.21

Given
$\theta_i = 56.0°$

$\theta_r = 22.0°$

$n_i = 1.00$

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

$$n_r = n_i\left[\frac{\left(\sin\theta_i\right)}{\left(\sin\theta_r\right)}\right] = (1.00)\left[\frac{(\sin 56.0°)}{(\sin 22.0°)}\right] = 2.21$$

32. 29.2°

Given
$\theta_i = 46.0°$

$n_{air} = 1.000$

$n_{ice} = 1.309$

$n_{glycerine} = 1.473$

Solution
First, determine the angle of refraction in ice.
Rearrange Snell's law, $n_i \sin\theta_i = n_r \sin\theta_r$, and solve for θ_r.

$$\theta_{r(ice)} = \sin^{-1}\left[\frac{n_i}{n_r}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{n_{air}}{n_{ice}}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{1.000}{1.309}\left(\sin 46.0°\right)\right] = 33.3°$$

Second, use $\theta_{r(ice)}$ as the angle of incidence for the ice-glycerine boundary and solve for $\theta_{r(glycerine)}$.

$$\theta_{r(glycerine)} = \sin^{-1}\left[\frac{n_i}{n_r}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{n_{ice}}{n_{glycerine}}\left(\sin\theta_{r(ice)}\right)\right] = \sin^{-1}\left[\frac{1.309}{1.453}\left(\sin 33.3°\right)\right] = 29.2°$$

33. 38.7°

Given
$\theta_i = 55.0°$

$n_{air} = 1.000$

$n_{carbon\ disulfide} = 1.628$

$n_{water} = 1.333$

Solution
First, determine the angle of refraction in carbon disulfide.
Rearrange Snell's law, $n_i \sin\theta_i = n_r \sin\theta_r$, and solve for θ_r.

$$\theta_{r(carbon\ disulfide)} = \sin^{-1}\left[\frac{n_i}{n_r}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{n_{air}}{n_{carbon\ disulfide}}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{1.000}{1.628}\left(\sin 55.0°\right)\right] = 30.2°$$

Second, use $\theta_{r(carbon\ disulfide)}$ as the angle of incidence for the carbon disulfide-water boundary and solve for $\theta_{r(water)}$.

$$\theta_{r(water)} = \sin^{-1}\left[\frac{n_i}{n_r}\left(\sin\theta_i\right)\right] = \sin^{-1}\left[\frac{n_{carbon\ disulfide}}{n_{water}}\left(\sin\theta_{r(carbon\ disulfide)}\right)\right] = \sin^{-1}\left[\frac{1.628}{1.309}\left(\sin 30.2°\right)\right] = 38.7°$$

34. 3.50

The image is three and a half times larger than the object. Since M is positive, the image is virtual and upright.

Given

$f = 10.0\text{ cm}$ (since this is a converging lens, the focal length is positive)

$q = -25.0\text{ cm}$ (since the image is located in front of the lens, q is negative)

Solution

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

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{10.0\text{ cm}} - \frac{1}{-25.0\text{ cm}} = \frac{0.100}{1\text{ cm}} + \frac{0.0400}{1\text{ cm}} = \frac{0.140}{1\text{ cm}}$$

$$p = 7.14\text{ cm}$$

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

$$M = -\frac{q}{p} = -\frac{(-25.0\text{ cm})}{(7.14\text{ cm})} = 3.50$$

The image is three and a half times larger than the object. Since M is positive, the image is virtual and upright.

35. 4.00 cm

Given

$h = 10.0\text{ cm}$

$p = 30.0\text{ cm}$

$f = -20.0\text{ cm}$ (since this is a diverging lens, the focal length is negative)

Solution

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

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{-20.0\text{ cm}} - \frac{1}{30.0\text{ cm}} = -\frac{0.0500}{1\text{ cm}} - \frac{0.0333}{1\text{ cm}} = -\frac{0.0833}{1\text{ cm}}$$

$$q = -12.0\text{ cm}$$

Rearrange the magnification of a lens equation, $M = \frac{h'}{h} = -\frac{q}{p}$, and solve for h'.

$$h' = -\frac{qh}{p} = -\frac{(-12.0\text{ cm})(10.0\text{ cm})}{(30.0\text{ cm})} = 4.00\text{ cm}$$

36. Since the angle of incidence, 59°, is less than the critical angle, 60.3°, the light ray will refract.

Given

$n_{liquid} = 1.75$

$n_{glass} = 1.52$

$\theta_i = 59°$

Solution

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

$$\theta_c = \sin^{-1}\left(\frac{n_r}{n_i}\right) = \sin^{-1}\left(\frac{n_{glass}}{n_{liquid}}\right) = \sin^{-1}\left(\frac{1.52}{1.75}\right) = 60.3°$$

Since the angle of incidence is less than the critical angle, the light ray will refract.