PHYSICS 4
CHAPTER 2 PROPERTIES OF LIGHT
EXERCISES

INTERFERENCE OF LIGHT WAVE

1. Two radio-frequency point sources S_1 and S_2, separated by distance d = 2.0 m, are radiating in phase with λ = 0.50 m. A detector moves in a large circular path around the two sources in a plane containing them. How many maxima does it detect?

2. A double-slit arrangement produces interference fringes for sodium light (λ = 589 nm) that have an angular separation of 3.50×10^{-3} rad. For what wavelength would the angular separation be 10.0% greater?

3. In a double-slit experiment, the distance between slits is 5.0 mm and the slits are 1.0 m from the screen. Two interference patterns can be seen on the screen: one due to light of wavelength 480 nm, and the other due to light of wavelength 600 nm. What is the separation on the screen between the third-order bright fringes of the two interference patterns?

4. A double-slit arrangement produces bright interference fringes for sodium light (λ = 589 nm) that are angularly separated by 0.30^o near the center of the pattern. What is the angular fringe separation if the entire arrangement is immersed in water, which has an index of refraction of 1 .33?

5. Light of wavelength 624 nm is incident perpendicularly on a soap film (n = 1.33) suspended in air. What are the
(a) least and
(b) second least thicknesses of the film
for which the reflections from the film undergo fully constructive interference.

6. White light, with a uniform intensity across the visible wavelength range of 400 to 690 nm, is perpendicularly incident on a water film, of index of refraction 1.33 and thickness L = 320 nm, that is suspended in air. At what wavelength λ is the light reflected by the film brightest to an observer?

7. We wish to coat flat glass (n = 1.50) with a transparent material (n = 1.25) so that reflection of light at wavelength 600 nm is eliminated by interference. What minimum thickness can the coating have to do this?

8. A soap bubble (*n* = 1.33) floating in air has the shape of a spherical shell with a wall thickness of 120 nm.
(a) What is the wavelength of the visible light that is most strongly reflected?
(b) Explain how a bubble of different thickness could also strongly reflect light of this same wavelength.
(c) Find the two smallest film thicknesses larger than 120 nm that can produce strongly reflected light of the same wavelength.

9. A thin film of oil (*n* = 1.25) is located on smooth, wet pavement. When viewed perpendicular to the pavement, the film reflects most strongly red light at 640 nm and reflects no green light at 512 nm. How thick is the oil film?

10. An oil film (*n* = 1.45) floating on water is illuminated by white light at normal incidence. The film is 280 nm thick. Find
(a) the wavelength and color of the light in the visible spectrum most strongly reflected and
(b) the wavelength and color of the light in the spectrum most strongly transmitted. Explain your reasoning.

DIFFRACTION - POLARIZATION

1. A slit of width *a* is illuminated by white light.
(a) For what value of *a* will the first minimum for red light of wavelength λ = 650 nm appear at $\theta = 15^o$?
(b) What is the wavelength λ' of the light whose first side diffraction maximum is at 15^o, thus coinciding with the first minimum for the red light?

2. Light of wavelength 633 nm is incident on a narrow slit. The angle between the first diffraction minimum on one side of the central maximum and the first minimum on the other side is 1.20^o.
What is the width of the slit?

3. A slit 1.00 mm wide is illuminated by light of wavelength 589 nm. We see a diffraction pattern on a screen 3.00 m away. What is the distance between the first two diffraction minima on the same side of the central diffraction maximum?

4. Light of wavelength 587.5 nm illuminates a slit of width 0.75 mm.

(a) At what distance from the slit should a screen be placed if the first minimum in the diffraction pattern is to be 0.85 mm from the central maximum?

(b) Calculate the width of the central maximum.

5. Helium–neon laser light (λ = 632.8 nm) is sent through a 0.300-mm-wide single slit. What is the width of the central maximum on a screen 1.00 m from the slit?

6. Sound with a frequency 650 Hz from a distant source passes through a doorway 1.10 m wide in a soundabsorbing wall. Find

(a) the number and

(b) the angular directions of the diffraction minima at listening positions along a line parallel to the wall.

7. The second-order dark fringe in a single-slit diffraction pattern is 1.40 mm from the center of the central maximum. Assuming the screen is 85.0 cm from a slit of width 0.800 mm and assuming monochromatic incident light, calculate the wavelength of the incident light.

8. Light from a helium–neon laser (λ = 632.8 nm) is incident on a single slit. What is the maximum width of the slit for which no diffraction minima are observed?

9. A helium–neon laser (λ = 632.8 nm) is used to calibrate a diffraction grating. If the first-order maximum occurs at 20.5°, what is the spacing between adjacent grooves in the grating?

10. White light is spread out into its spectral components by a diffraction grating. If the grating has 2 000 grooves per centimeter, at what angle does red light of wavelength 640 nm appear in first order?

11. If the spacing between planes of atoms in a NaCl crystal is 0.281 nm, what is the predicted angle at which 0.140-nm x-rays are diffracted in a first-order maximum?

12. Potassium iodide (KI) has the same crystalline structure as NaCl, with atomic planes separated by 0.353 nm. A monochromatic x-ray beam shows a first-order diffraction maximum when the grazing angle is 7.60°. Calculate the x-ray wavelength.

13. Monochromatic x-rays (l 5 0.166 nm) from a nickel target are incident on a potassium chloride (KCl) crystal surface. The spacing between planes of atoms inKCl is 0.314 nm. At what angle (relative to the surface) should the beam be directed for a second-order maximum to be observed?

14. The first-order diffraction maximum is observed at 12.6° for a crystal having a spacing between planes of atoms of 0.250 nm.

(a) What wavelength x-ray is used to observe this first-order pattern?

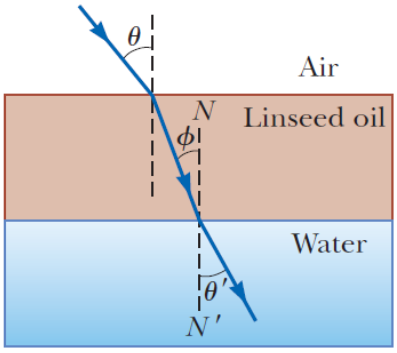
(b) How many orders can be observed for this crystal at this wavelength?

LAWS OF GEOMETRIC OPTICS

1. A ray of light is incident on a flat surface of a block of crown glass that is surrounded by water. The angle of refraction is 19.6°. Find the angle of reflection.

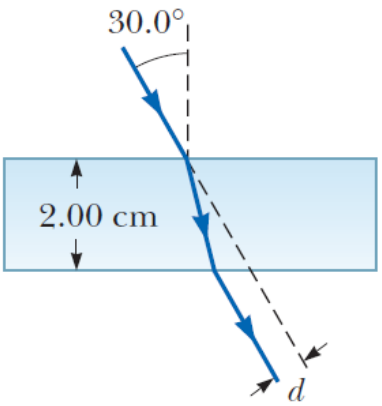
2. The figure shows a refracted light beam in linseed oil making an angle of 20.0° with the normal line *NN*'. The index of refraction of linseed oil is 1.48.

Determine the angles (a) θ and (b) θ'.



3. A light ray initially in water enters a transparent substance at an angle of incidence of 37.0°, and the transmitted ray is refracted at an angle of 25.0°. Calculate the speed of light in the transparent substance.

4. A laser beam is incident at an angle of 30.0° from the vertical onto a solution of corn syrup in water. The beam is refracted to 19.24° from the vertical.
(a) What is the index of refraction of the corn syrup solution?
Assume that the light is red, with vacuum wavelength 632.8 nm. Find its
(b) wavelength,
(c) frequency, and
(d) speed in the solution.
5. A ray of light strikes the midpoint of one face of an equiangular (60°–60°–60°) glass prism (n = 1.5) at an angle of incidence of 30°.
(a) Trace the path of the light ray through the glass and find the angles of incidence and refraction at each surface.
(b) If a small fraction of light is also reflected at each surface, what are the angles of reflection at the surfaces?
6. When the light ray illustrated in the figure passes through the glass block of index of refraction n 5 1.50, it is shifted laterally by the distance d.
(a) Find the value of d.
(b) Find the time interval required for the light to pass through the glass block.



7. A 4.00-m-long pole stands vertically in a freshwater lake having a depth of 2.00 m. The Sun is 40.0° above the horizontal. Determine the length of the pole's shadow on the bottom of the lake.
8. The index of refraction for red light in water is 1.331 and that for blue light is 1.340. If a ray of white light enters the water at an angle of incidence of 83.0°, what are the underwater angles of refraction for the
(a) red and
(b) blue components of the light?
9. A glass optical fiber (n = 1.50) is submerged in water (n = 1.33). What is the critical angle for light to stay inside the fiber?
10. A beam of light is incident from air on the surface of a liquid. If the angle of incidence is 30.0° and the angle of refraction is 22.0°, find the critical angle for total internal reflection for the liquid when surrounded by air.

IMAGE FORMATION
1. Determine the minimum height of a vertical flat mirror in which a person 178 cm tall can see his or her full image.
2. An object is placed 50.0 cm from a concave spherical mirror with focal length of magnitude 20.0 cm.
(a) Find the location of the image.
(b) What is the magnification of the image?
(c) Is the image real or virtual?
(d) Is the image upright or inverted?
3. A concave spherical mirror has a radius of curvature of magnitude 20.0 cm.
(a) Find the location of the image for object distances of
(i) 40.0 cm,
(ii) 20.0 cm, and
(iii) 10.0 cm.
For each case, state whether the image is
(b) real or virtual and
(c) upright or inverted.
(d) Find the magnification in each case.
4. (a) A concave spherical mirror forms an inverted image 4.00 times larger than the object. Assuming the distance between object and image is 0.600 m, find the focal length of the mirror. (b) Suppose the

mirror is convex. The distance between the image and the object is the same as in part (a), but the image is 0.500 the size of the object. Determine the focal length of the mirror.

5. An object 10.0 cm tall is placed at the zero mark of a meterstick. A spherical mirror located at some point on the meterstick creates an image of the object that is upright, 4.00 cm tall, and located at the 42.0-cm mark of the meterstick.

(a) Is the mirror convex or concave?

(b) Where is the mirror?

(c) What is the mirror's focal length?

6. A convex spherical mirror has a focal length of magnitude 8.00 cm.

(a) What is the location of an object for which the magnitude of the image distance is one third the magnitude of the object distance?

(b) Find the magnification of the image and

(c) state whether it is upright or inverted.

7. A movie camera with a (single) lens of focal length 75 mm takes a picture of a person standing 27 m away. If the person is 180 cm tall, what is the height of the image on the film?

8. A lens is made of glass having an index of refraction of 1.5. One side of the lens is flat, and the other is convex with a radius of curvature of 20 cm.

(a) Find the focal length of the lens.

(b) If an object is placed 40cm in front of the lens, where will the image be located?

9. An object is located 20.0 cm to the left of a diverging lens having a focal length f = 232.0 cm. Determine

(a) the location and

(b) the magnification of the image.

(c) Construct a ray diagram for this arrangement.

10. The projection lens in a certain slide projector is a single thin lens. A slide 24.0 mm high is to be projected so that its image fills a screen 1.80 m high. The slide-to-screen distance is 3.00 m. (a) Determine the focal length of the projection lens.

(b) How far from the slide should the lens of the projector be placed so as to form the image on the screen?

11. An eraser of height 1.0 cm is placed 10.0 cm in front of a two-lens system. Lens 1 (nearer the eraser) has focal length f_1 = -15 cm, lens 2 has f_2 = 12cm, and the lens separation is d = 12cm. For the image produced by lens 2,what are

(a) the image distance i_2 (including sign),

(b) the image height,

(c) the image type (real or virtual), and

(d) the image orientation (inverted relative to the eraser or not inverted)?

12. A coin is placed 20 cm in front of a two-lens system. Lens 1 (nearer the coin) has focal length f_1 = + 10 cm, lens 2 has f_2 = +12.5 cm, and the lens separation is d = 30 cm. For the image produced by lens 2, what are

(a) the image distance,

(b) the overall lateral magnification,

(c) the image type (real or virtual), and

(d) the image orientation (inverted relative to the coin or not inverted)?

13. An object is placed 12.0 cm to the left of a diverging lens of focal length 26.00 cm. A converging lens of focal length 12.0 cm is placed a distance d to the right of the diverging lens. Find the distance d so that the final image is infinitely far away to the right.

14. An object is placed a distance p to the left of a diverging lens of focal length f_1. A converging lens of focal length f_2 is placed a distance d to the right of the diverging lens. Find the distance d so that the final image is infinitely far away to the right.