Chapter 24
Conceptual Questions and Concepts and Calculations

CONCEPTUAL QUESTIONS

ssm Solution is in the Student Solutions Manual.

1. Which of the following concepts applies to both sound waves and electromagnetic waves: (a) intensity or (b) polarization? Account for your answer.

2. Refer to Figure 24.2. Between the times indicated in parts *c* and *d* in the drawing, what is the direction of the magnetic field at the point *P* for the electromagnetic wave being generated? Is it directed into or out of the plane of the paper? Justify your answer.

3. **ssm** A transmitting antenna is located at the origin of an *x*, *y*, *z* axis system and broadcasts an electromagnetic wave whose electric field oscillates along the *y* axis. The wave travels along the $+x$ axis. Three possible wire loops are available for use with an LC-tuned circuit to detect this wave: One loop lies in the *xy* plane, another in the *xz* plane, and the third in the *yz* plane. Which of the loops will detect the wave? Why?

4. Why does the peak value of the emf induced in a loop antenna (see Figure 24.6) depend on the frequency of the electromagnetic wave, whereas the peak value of the emf induced in a straight-wire antenna (see Figure 24.5) does not?

5. Suppose that the electric field of an electromagnetic wave decreases in magnitude. Does the magnetic field increase, decrease, or remain the same? Account for your answer.

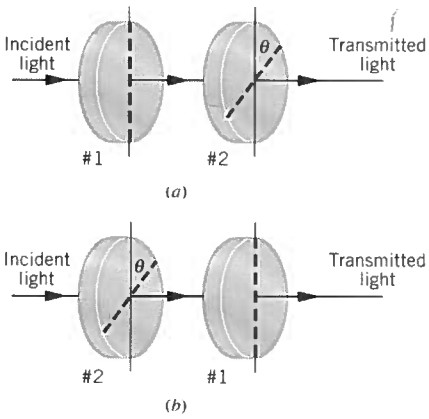
6. ssm An astronomer measures the Doppler change in frequency for the light reaching the earth from a distant star. From this measurement, can the astronomer tell whether the star is moving away from the earth or whether the earth is moving away from the star? Explain.

7. Is there any real difference between a polarizer and an analyzer? In other words, can a polarizer be used as an analyzer, and vice versa?

8. Malus' law applies to the setup in Figure 24.21, which shows the analyzer rotated through an angle θ and the polarizer held fixed. Does Malus' law apply when the analyzer is held fixed and the polarizer is rotated? Give your reasoning.

9. In Example 7, we saw that when the angle between the polarizer and analyzer is 63.4°, the intensity of the transmitted light drops to one-tenth of that of the incident unpolarized light. What happens to the light intensity that is not transmitted?

10. Light is incident from the left on two pieces of polarizing material, 1 and 2. As part *a* of the drawing illustrates, the transmission axis of material 1 is along the vertical direction, and that of material 2 makes an angle of θ with respect to the vertical. In part *b* of the drawing the two polarizing materials are interchanged. (a) Assume that the incident light is unpolarized and determine whether the intensity of the transmitted light in drawing *a* is greater than, equal to, or less than that in drawing *b*. (b) Repeat part (a), assuming that the incident light is linearly polarized along the vertical direction. Justify your answers to both parts (a) and (b).



11. ssm You are sitting upright on the beach near a lake on a sunny day, wearing Polaroid sunglasses. When you lie down on your side, facing the lake, the sunglasses don't work as well as they did while you were sitting upright. Why not?

CONCEPTS & CALCULATIONS

Note: Each of these problems consists of Concept Questions followed by a related quantitative Problem. The Concept Questions involve little or no mathematics. They focus on the concepts with which the problems deal. Recognizing the concepts is the essential initial step in any problem-solving technique.

55. GO **Concept Questions** A certain type of laser emits light of known frequency. The light, however, occurs as a series of short pulses, each lasting for a time t_0. (a) How is the wavelength of the light related to its frequency? (b) How is the length (in meters) of each pulse related to the time t_0?

Problem A laser emits a pulse of light that lasts for 2.7×10^{-11} s. The frequency of the light is 5.2×10^{14} Hz. (a) How many wavelengths are there in one pulse? (b) The light enters a pool of water. Its frequency remains the same, but the light slows down to a speed of 2.3×10^{8} m/s. How many wavelengths are there now in one pulse?

56. GO **Concept Questions** (a) Suppose that the magnitude E of the electric field in an electromagnetic wave triples. By what factor does the intensity S of the wave change? (b) The magnitude B of the magnetic field is much smaller than E because, according to Equation 24.3, $B = E/c$, where c is the speed of light in a vacuum. If B triples, by what factor does the intensity change? Account for your answers.

Problem The magnitude of the electric field of an electromagnetic wave increases from 315 to 945 N/C. (a) Determine the intensities for the two values of the electric field. (b) What is the magnitude of the magnetic field associated with each electric field? (c) Determine the intensity for each value of the magnetic field. Make sure your answers are consistent with your answers to the Concept Questions.

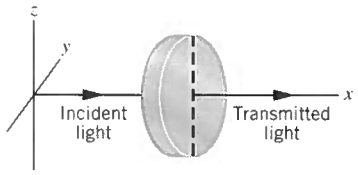
57. GO **Concept Questions** Consult Multiple-Concept Example 5 to review the concepts on which this problem depends. A source is radiating light waves uniformly in all directions. At a certain distance r from the source a person measures the average intensity of the waves. (a) Does the average intensity increase, decrease, or remain the same, as r increases? (b) If the magnitude of the electric field is determined from the average intensity, is the electric field the rms value or the peak value? In both cases, justify your answers.

Problem A light bulb emits light uniformly in all directions. The average emitted power is 150.0 W. At a distance of 5.00 m from the bulb, determine (a) the average intensity of the light, (b) the rms value of the electric field, and (c) the peak value of the electric field.

58. GO **Concept Questions** An electric charge is placed in a laser beam. Does a stationary charge experience a force due to (a) the electric field and (b) the magnetic field of the electromagnetic wave? Now suppose that the charge is moving perpendicular to the magnetic field of the beam. Does it experience (c) an electric force and (d) a magnetic force? Account for your answers.

Problem A stationary particle of charge $q = 2.6 \times 10^{-8}$ C is placed in a laser beam whose intensity is 2.5×10^3 W/m^2. Determine the magnitude of the (a) electric and (b) magnetic forces exerted on the charge. If the charge is moving perpendicular to the magnetic field with a speed of 3.7×10^4 m/s, find the magnitudes of the (c) electric and (d) magnetic forces exerted on it. Verify that your answers are consistent with your answers to the Concept Questions.

59. GO **Concept Questions** The drawing shows light incident on a polarizer whose transmission axis is parallel to the z axis. The polarizer is rotated clockwise through an angle α between 0 and 90°. While the polarizer is being rotated, does the average intensity of the transmitted light increase, decrease, or remain the same if the incident light is (a) unpolarized, (b) polarized parallel to the z axis, and (c) polarized parallel to the y axis? Provide a reason for each of your answers.

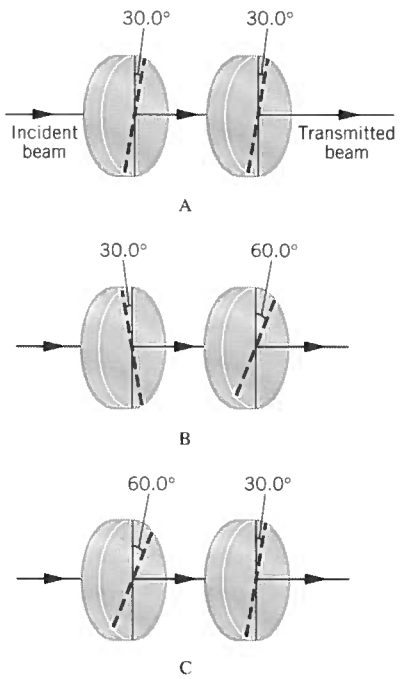


Problem The average intensity of the incident light is 7.0 W/m^2. Determine the average intensity of the transmitted light for each of the six cases shown in the table.

	Intensity of Transmitted Light	
Incident Light	$\alpha = 0°$	$\alpha = 35°$
Unpolarized		
Polarized parallel to z axis		
Polarized parallel to y axis		

Be sure that your answers are consistent with your answers to the Concept Questions.

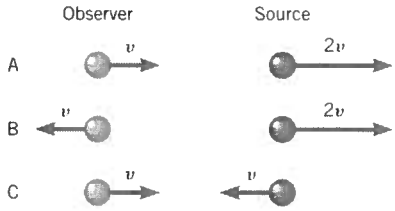
60. GO **Concept Question** The drawing shows three polarizer/analyzer pairs. The incident light on each pair is unpolarized and has the same average intensity. Rank the pairs according to the average intensity of the transmitted light, largest first. Provide reasons for your answers.



Problem The average intensity of the unpolarized incident beam is 48 W/m^2. Find the average intensity of the transmitted beams for each of the three cases shown in the drawing. Be sure your answers are consistent with your answer to the Concept Question.

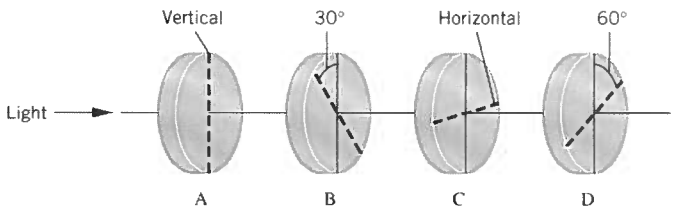
* **61.** GO **Concept Question** The drawing shows three situations A, B, and C in which an observer and a source of electromagnetic waves are moving along the same line. In each case the source emits a wave of the same frequency. The arrows in each situation denote velocity vectors relative to the ground and have the magnitudes indicated, either v or $2v$. Rank the frequencies of the observed electromagnetic waves in descending order (largest first) according to magnitude. Explain your reasoning.

Problem Each of the sources in the drawing emits a frequency of 4.57×10^{14} Hz, and the speed v is 1.50×10^6 m/s. Calculate the observed frequency in each of the three cases. Verify that your answers are consistent with your answer to the Concept Question.



* **62.** GO **Concept Questions** The drawing shows four sheets of polarizing material, each with its transmission axis oriented differently. Light that is polarized in the vertical direction is incident from the left. One of the sheets is to be removed, with the goal of having some light still pass through the remaining three sheets and emerge on the right. (a) There are a number of possibilities for the sheet that is removed. What are they? Account for your answer. (b) Of the possibilities identified in Concept Question (a), which one allows the greatest average light intensity to pass through the sheets? Justify your answer.

Problem The light incident from the left in the drawing has an average intensity of 27 W/m^2. For each of the possibilities identified in Concept Question (a), determine the average intensity of the light that emerges on the right in the drawing. Be sure that your answer is consistent with your answer to Concept Question (b).



Chapter 25
Conceptual Questions and Concepts and Calculations

CONCEPTUAL QUESTIONS

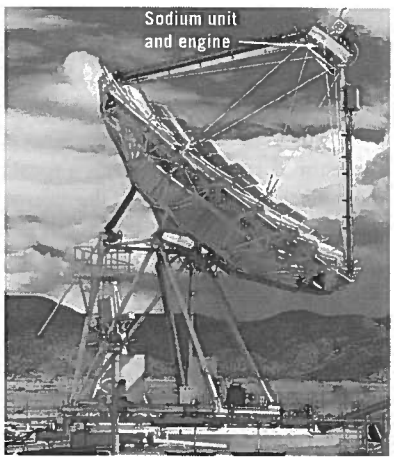
ssm Solution is in the Student Solutions Manual.

1. ssm A sign painted on a store window is reversed when viewed from inside the store. If a person inside the store views the reversed sign in a plane mirror, does the sign appear as it would when viewed from outside the store? (Try it by writing some letters on a transparent sheet of paper and then holding the back side of the paper up to a mirror.) Explain.

2. If a clock is held in front of a mirror, its image is reversed left to right. From the point of view of a person looking into the mirror, does the image of the second hand rotate in the reverse (counterclockwise) direction? Justify your answer.

3. (a) Which kind of spherical mirror, concave or convex, can be used to start a fire with sunlight? (b) For the best results, how far from the mirror should the paper to be ignited be placed? Explain your answers.

4. The photograph shows an experimental device at Sandia National Laboratories in New Mexico. This device is a mirror that focuses sunlight to heat sodium to a boil, which then heats helium gas in an engine. The engine does the work of driving a generator to produce electricity. The sodium unit and the engine are labeled in the photo. (a) What kind of mirror is being used, and (b) where is the sodium unit located relative to the mirror? Express your answer in terms of the focal length of the mirror. Give your reasoning.



(Courtesy Sandia National Laboratories)

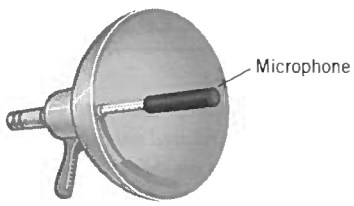
5. Refer to Figure 25.14 and the related discussion about spherical aberration. To bring the top ray closer to the focal point F after reflection, describe how you would change the shape of the mirror. Would you open it up to produce a more gently curving shape or bring the top and bottom edges closer to the principal axis? Account for your answer using the law of reflection.

6. (a) Can the image formed by a concave mirror ever be projected directly onto a screen, without the help of other mirrors or lenses? If so, specify where the object should be placed relative to the mirror. (b) Repeat part (a) assuming that the mirror is convex.

7. (a) When you look at the back side of a shiny teaspoon, held at arm's length, you see yourself upright. Why? (b) When you look at the other side of the spoon, you see yourself upside down. Why?

8. ssm If you stand between two parallel plane mirrors, you see an infinite number of images of yourself. This occurs because an image in one mirror is reflected in the other mirror to produce another image, which is then re-reflected, and so forth. The multiple images are equally spaced. Suppose that you are facing a convex mirror, with a plane mirror behind you. Describe what you would see and comment about the spacing between any multiple images. Explain your reasoning.

9. Sometimes news personnel covering an event use a microphone arrangement that is designed to increase the ability of the mike to pick up weak sounds. The drawing shows that the arrangement consists of a hollowed-out shell behind the mike. The shell acts like a mirror for sound waves. Explain how this arrangement enables the mike to detect weak sounds.



10. When you see the image of yourself formed by a mirror, it is because (1) light rays actually coming from a real image enter your eyes or (2) light rays appearing to come from a virtual image enter your eyes. If light rays from the image do not enter your eyes, you do not see yourself. Are there any places on the principal axis where you cannot see yourself when you are in front of a mirror that is (a) convex and (b) concave? If so, where are these places?

11. Concept Simulation 25.3 at **www.wiley.com/college/cutnell** reviews the concepts that are important in this question. Plane mirrors and convex mirrors form virtual images. With a plane mirror, the image may be infinitely far behind the mirror, depending on where the object is located in front of the mirror. For an object in front of a single convex mirror, what is the greatest distance behind the mirror at which the image can be found? Justify your answer.

12. Concept Simulation 25.3 at **www.wiley.com/college/cutnell** allows you to explore the concepts to which this question relates. Is it possible to use a convex mirror to produce an image that is larger than the object? Provide a reason for your answer.

13. ssm Suppose you stand in front of a spherical mirror (concave or convex). Is it possible for your image to be (a) real and upright or (b) virtual and inverted? Justify your answers.

CONCEPTS & CALCULATIONS

Note: Each of these problems consists of Concept Questions followed by a related quantitative Problem. The Concept Questions involve little or no mathematics. They focus on the concepts with which the problems deal. Recognizing the concepts is the essential initial step in any problem-solving technique.

42. GO **Concept Questions** A small mirror is attached to a vertical wall, and it hangs a distance y above the floor. A ray of sunlight strikes the mirror, and the reflected ray forms a spot on the floor. (a) From a knowledge of y and the horizontal distance x from the base of the wall to the spot, describe how one can determine the angle of incidence of the ray striking the mirror. If it is morning and the mirror is facing due east, would (b) the angle of incidence and (c) the distance x increase or decrease in time? Why?

Problem Suppose the mirror is 1.80 m above the floor. The reflected ray of sunlight strikes the floor at a distance of 3.86 m from the base of the wall. Later in the morning, the ray is observed to strike the floor at a distance of 1.26 m from the wall. The earth rotates at a rate of 15.0° per hour. How much time (in hours) has elapsed between the two observations?

43. GO **Concept Questions** (a) Suppose that you are walking perpendicularly toward a stationary plane mirror. Following the method discussed in Section 3.4, express your image's velocity $\vec{\mathbf{v}}_{\mathbf{IY}}$ relative to you in terms of the image's velocity $\vec{\mathbf{v}}_{\mathbf{IM}}$ relative to the mirror and the mirror's velocity $\vec{\mathbf{v}}_{\mathbf{MY}}$ relative to you. (b) How is the mirror's velocity $\vec{\mathbf{v}}_{\mathbf{MY}}$ relative to you related to your velocity $\vec{\mathbf{v}}_{\mathbf{YM}}$ relative to the mirror? Explain. (c) Consider both velocities $\vec{\mathbf{v}}_{\mathbf{YM}}$ and $\vec{\mathbf{v}}_{\mathbf{IM}}$. Do they have the same magnitudes and the same directions? Explain.

Problem When you walk perpendicularly with a velocity of +0.90 m/s toward a stationary plane mirror, what is the velocity of your image relative to you? The direction in which you walk is the positive direction.

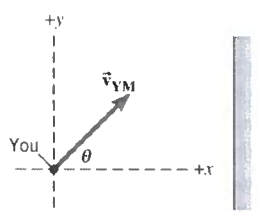
44. GO **Concept Questions** (a) For an inverted image that is in front of a mirror, is the image distance positive or negative and is the image height positive or negative? Explain. (b) Given the image distance, what additional information is needed to determine the focal length? Explain. (c) Given the object and image heights and a statement as to whether the image is upright or inverted, what additional information is needed to determine the object distance?

Problem A small statue has a height of 3.5 cm and is placed in front of a concave mirror. The image of the statue is inverted, 1.5 cm tall, and is located 13 cm in front of the mirror. Find the focal length of the mirror.

45. GO **Concept Questions** These questions refer to Figure 25.22*a*. (a) As the object distance increases, does reflected ray 1 change? (b) As the object distance increases, does reflected ray 3 make a greater or smaller angle with respect to the principal axis? (c) Extending the reflected rays 1 and 3 behind the mirror allows us to locate the top of the image. As the object distance increases, does the image height increase or decrease?

Problem A convex mirror has a focal length of −27.0 cm. Find the magnification produced by the mirror when the object distance is 9.0 cm and 18.0 cm. Verify that your answers are consistent with your answers to the Concept Questions.

46. GO **Concept Questions** (a) Suppose that you are walking toward a stationary plane mirror as in the drawing. The view is from above. Following the method discussed in Section 3.4, express your image's velocity $\vec{\mathbf{v}}_{\mathbf{IY}}$ relative to you in terms of the image's velocity $\vec{\mathbf{v}}_{\mathbf{IM}}$ relative to the mirror and the mirror's velocity $\vec{\mathbf{v}}_{\mathbf{MY}}$ relative to you. (b) How is the mirror's velocity $\vec{\mathbf{v}}_{\mathbf{MY}}$ relative to you related to your velocity $\vec{\mathbf{v}}_{\mathbf{YM}}$ relative to the mirror? Explain. (c) Consider both velocities $\vec{\mathbf{v}}_{\mathbf{YM}}$ and $\vec{\mathbf{v}}_{\mathbf{IM}}$. Do they have the same x and y components? Explain.



Problem You walk at an angle of $\theta = 50.0°$ toward a plane mirror, as in the drawing. Your walking velocity has a magnitude of 0.90 m/s. What is the velocity of your image relative to you (magnitude and direction)?

47. GO **Concept Questions** A tall tree is growing across a river from you. You would like to know the distance between yourself and the tree, as well as its height, but are unable to make the measurements directly. However, by using a mirror to form an image of the tree, and then measuring the image distance and the image height, you can calculate the distance to the tree, as well as its height. (a) What kind of mirror, concave or convex, must you use? Why? (b) You will need to know the focal length of the mirror. The sun is shining. You aim the mirror at the sun and form an image of it. How is the image distance of the sun related to the focal length of the mirror? (c) Having measured the image distance d_i and the image height h_i of the tree, as well as the image distance of the sun, describe how you would use these numbers to determine the distance and height of the tree.

Problem A mirror produces an image of the sun, and the image is located 0.9000 m from the mirror. The same mirror is then used to produce an image of the tree. The image of the tree is 0.9100 m from the mirror. (a) How far away is the tree? (b) The image height of the tree has a magnitude of 0.12 m. How tall is the tree?

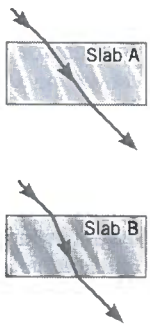
Chapter 26
Conceptual Questions and Concepts and Calculations

CONCEPTUAL QUESTIONS

ssm Solution is in the Student Solutions Manual.

1. In Figure 26.1*a*, suppose that a layer of oil were added on top of the water. The angle θ_1 at which the incident light travels through the air remains the same. Assuming that light still enters the water, does the angle of refraction at which it does so change because of the presence of the oil? Explain.

2. Two slabs with parallel faces are made from different types of glass. A ray of light travels through air and enters each slab at the same angle of incidence, as the drawing shows. Which slab has the greater index of refraction? Why?



Question 2

3. When an observer peers over the edge of a deep empty bowl, he does not see the entire bottom surface, so a small object lying on the bottom is hidden from view. However, when the bowl is filled with water, the object can be seen. Explain this effect.

4. **ssm** Two identical containers, one filled with water ($n = 1.33$) and the other filled with ethyl alcohol ($n = 1.36$), are viewed from directly above. Which container (if either) appears to have a greater depth of fluid? Why?

5. When you look through an aquarium window at a fish, is the fish as close as it appears? Explain.

6. At night, when it's dark outside and you are standing in a brightly lit room, it is easy to see your reflection in a window. During the day it is not so easy. Account for these facts.

7. A man is fishing from a dock. (a) If he is using a bow and arrow, should he aim above the fish, at the fish, or below the fish, to strike it? (b) How would he aim if he were using a laser gun? Give your reasoning.

8. Two rays of light converge to a point on a screen. A plane-parallel plate of glass is placed in the path of this converging light, and the glass plate is parallel to the screen. Will the point of convergence remain on the screen? If not, will the point move toward the glass or away from it? Justify your answer by drawing a diagram and showing how the rays are affected by the glass.

9. A person sitting at the beach is wearing a pair of Polaroid sunglasses and notices little discomfort due to the glare from the water on a bright sunny day. When she lies on her side, however, she notices that the glare increases. Why?

10. You are sitting by the shore of a lake on a sunny and windless day. Your Polaroid sunglasses are not equally effective at all times of the day in reducing the glare of the sunlight reflected from the lake. Account for this observation.

11. The dispersion of sunlight by a prism is discussed in connection with Figure 26.18. Is it possible to direct a mixture of colors into a prism and have sunlight emerge from it? If so, explain how this could be done.

12. Refer to Figure 26.6. Note that the ray within the glass slab is traveling from a medium with a larger refractive index toward a medium with a smaller refractive index. Is it possible, for θ_1 less than 90°, that the ray within the glass will experience total internal reflection at the glass–air interface? Account for your answer.

13. Suppose you want to make a rainbow by spraying water from a garden hose into the air. (a) Where must you stand relative to the water and the sun to see the rainbow? (b) Why can't you ever walk under the rainbow?

14. **ssm** A person is floating on an air mattress in the middle of a swimming pool. His friend is sitting on the side of the pool. The person on the air mattress claims that there is a light shining up from the bottom of the pool directly beneath him. His friend insists, however, that she cannot see any light from where she sits on the side. Can both individuals be correct? Give your reasoning.

15. A beam of blue light is propagating in glass. When the light reaches the boundary between the glass and the surrounding air, the beam is totally reflected back into the glass. However, red light with the same angle of incidence is not totally reflected, and some of the light is refracted into the air. Why do these two colors behave differently?

16. A beacon in a lighthouse is to produce a parallel beam of light. The beacon consists of a light bulb and a converging lens. Should the bulb be placed outside the focal point, at the focal point, or inside the focal point of the lens? State your reason.

17. Review Conceptual Example 8 as an aid in answering this question. Is it possible that a converging lens (in air) behaves as a

diverging lens when surrounded by another medium? Give a reason for your answer.

18. A spherical mirror and a lens are immersed in water. Compared to the way they work in air, which one do you expect will be more affected by the water? Why?

19. A converging lens is used to project a real image onto a screen, as in Figure 26.27*b*. A piece of black tape is then placed over the upper half of the lens. Will only the lower half of the image be visible on the screen? Justify your answer by drawing rays from various points on the object to the corresponding points on the image.

20. Review Conceptual Example 8 as an aid in answering this question. A converging lens is made from glass whose index of refraction is n. The lens is surrounded by a fluid whose index of refraction is also n. Can this lens still form an image, either real or virtual, of an object? Why?

21. **ssm** In a TV mystery program, a photographic negative is introduced as evidence in a court trial. The negative shows an image of a house (now burned down) that was the scene of the crime. At the trial the defendant's acquittal depends on knowing exactly how far above the ground a window was. An expert called by the defense claims that this height can be calculated from only two pieces of information: (1) the measured height on the film, and (2) the focal length of the camera lens. Explain whether the expert is making sense, using the thin-lens and magnification equations to guide your thinking.

22. Two people who wear glasses are camping. One is nearsighted and the other is farsighted. Whose glasses may be useful in starting a fire with the sun's rays? Give your reasoning.

23. Suppose that a 21-year-old with normal vision (near point = 25 cm) is standing in front of a plane mirror. How close can he stand to the mirror and still see himself in focus? Explain.

24. If we read for a long time, our eyes become "tired." When this happens, it helps to stop reading and look at a distant object. From the point of view of the ciliary muscle, why does this refresh the eyes?

25. To a swimmer under water, objects look blurred and out of focus. However, when the swimmer wears goggles that keep the water away from the eyes, the objects appear sharp and in focus. Why do goggles improve a swimmer's underwater vision?

26. The refractive power of the lens of the eye is 15 diopters when surrounded by the aqueous and vitreous humors. If this lens is removed from the eye and surrounded by air, its refractive power increases to about 150 diopters. Why is the refractive power of the lens so much greater outside the eye?

27. The light shining through a full glass of wine forms an irregularly shaped bright spot on the table, but does not do so when the glass is empty. Explain.

28. Jupiter is the largest planet in our solar system. Yet, to the naked eye, it looks smaller than Venus. Why?

29. Try using **Concept Simulations 26.3** and **26.4** at **www.wiley.com/college/cutnell** to guide your reasoning here. By means of a ray diagram, show that the eyes of a person wearing glasses appear to be (a) smaller when the glasses use diverging lenses to correct for nearsightedness and (b) larger when the glasses use converging lenses to correct for farsightedness.

30. Can a diverging lens be used as a magnifying glass? Justify your answer with a ray diagram.

31. Who benefits more from using a magnifying glass, a person whose near point is located 25 cm away from the eyes or a person whose near point is located 75 cm away from the eyes? Provide a reason for your answer.

32. Two lenses, whose focal lengths are 3 and 45 cm, are used to build a telescope. Which lens should be the objective? Why?

33. Two refracting telescopes have identical eyepieces, although one telescope is twice as long as the other. Which has the greater angular magnification? Provide a reason for your answer.

34. Suppose a well-designed optical instrument is composed of two converging lenses separated by 14 cm. The focal lengths of the lenses are 0.60 and 4.5 cm. Is the instrument a microscope or a telescope? Why?

35. It is often thought that virtual images are somehow less important than real images. To show that this is not true, identify which of the following instruments normally produce final images that are virtual: (a) a projector, (b) a camera, (c) a magnifying glass, (d) eyeglasses, (e) a compound microscope, and (f) an astronomical telescope.

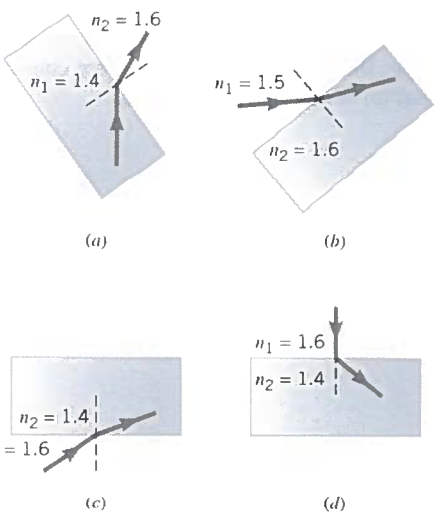
36. Why does chromatic aberration occur in lenses, but not in mirrors?

CONCEPTS & CALCULATIONS

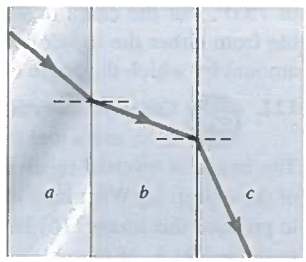
Note: Each of these problems consists of Concept Questions followed by a related quantitative Problem. The Concept Questions involve little or no mathematics. They focus on the concepts with which the problems deal. Recognizing the concepts is the essential initial step in any problem-solving technique.

118. GO **Concept Question** The drawing shows four different situations in which a light ray is traveling from one medium into another. Without doing any calculations, but taking note of the relative sizes of the angles of incidence and refraction, decide which situations (if any) show a refraction that is physically possible. Provide a reason as to why the refraction is possible or impossible.

Problem For cases (*a*), (*b*), and (*c*), the angle of incidence is 55°; for case (*d*), the angle of incidence is 0°. For each case, determine the angle of refraction. Check to be sure that your answers are consistent with your answers to the Concept Question.

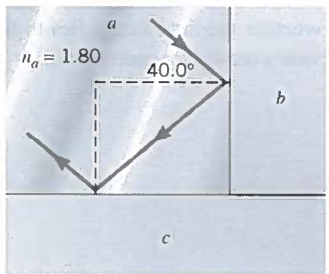


119. GO **Concept Question** The drawing shows a ray of light traveling through three materials whose surfaces are parallel to each other. The refracted rays (but not the reflected rays) are shown as the light passes through each material. Taking into account the relative sizes of the angles of incidence and refraction, rank the materials according to their indices of refraction, greatest first. Provide reasons for your ranking.



Problem A ray of light strikes the a–b interface at a 50.0° angle of incidence. The index of refraction of material a is $n_a = 1.20$. The angles of refraction in materials b and c are, respectively, 45.0° and 56.7°. Find the indices of refraction in these two media. Verify that your answers are consistent with your answers to the Concept Question.

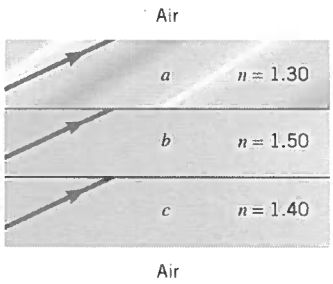
120. GO **Concept Question** The drawing shows three materials, a, b, and c. A ray of light strikes the a–b interface at an angle of incidence that just barely exceeds its critical angle. The reflected ray then strikes the a–c interface at an angle of incidence that just barely exceeds its critical angle. Rank the three materials according to their indices of refraction, largest first.



Problem A ray of light is incident at the a–b interface with an angle of incidence that just barely exceeds the critical angle of $\theta_c = 40.0°$. The index of refraction of material a is $n_a = 1.80$. Find the indices of refraction for the two other materials. Be sure your

ranking of the indices is consistent with that determined in the Concept Question.

121. GO **Concept Question** The drawing shows three layers of different materials, with air above and below the layers. The interfaces between the layers are parallel. The index of refraction of each layer is given in the drawing. Identical rays of light are sent into the layers, and each ray zigzags through the layer, reflecting from the top and bottom surfaces. Fill in the following table specifying a "yes" or "no" as to whether total internal reflection is possible from the top and bottom surfaces of each layer. Provide a reason for each of your answers.



	Is total internal reflection possible?	
Layer	Top surface of layer	Bottom surface of layer
a		
b		
c		

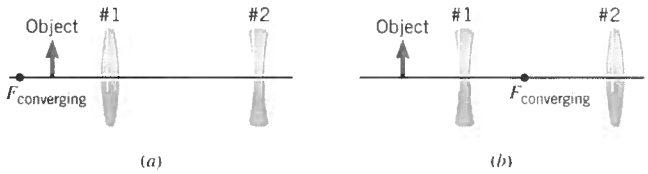
Problem For each layer, the ray of light has an angle of incidence of 75.0°. For the cases in which total internal reflection is possible from either the top or bottom surface of a layer, determine the amount by which the angle of incidence exceeds the critical angle.

122. GO **Concept Questions** An object is placed to the left of a lens, and a real image is formed to the right of the lens. The image is inverted relative to the object and is one-half the size of the object. (a) What kind of lens, converging or diverging, is used to produce this image? (b) How is the height h_i of the image related to the height h_o of the object? Don't forget to take into account the fact that the image is inverted relative to the object. (c) What is the ratio d_i/d_o of the image distance to the object distance?

Problem For the situation described in the Concept Questions, the distance between the object and the image is 90.0 cm. (a) How far from the lens is the object? (b) What is the focal length of the lens?

123. GO **Concept Question** Two systems are formed from a converging lens and a diverging lens, as shown in parts *a* and *b* of the drawing. (The point labeled "$F_{\text{converging}}$" is the focal point of the converging lens.) An object is placed inside the focal point of lens 1. Without doing any calculations, determine for each system whether the final image lies to the left or to the right of lens 2. Provide a reason for each answer.

Problem The focal lengths of the converging and diverging lenses are 15.00 and −20.0 cm, respectively. The distance between the lenses is 50.0 cm, and an object is placed 10.00 cm to the left of lens 1. Determine the final image distance for each system, measured with respect to lens 2. Check to be sure your answers are consistent with your answers to the Concept Question.



* **124.** GO **Concept Questions** The back wall of a home aquarium is a mirror that is a distance L away from the front wall. The walls of the tank are negligibly thin. A fish, swimming midway between the front and back walls, is being viewed by a person looking through the front wall. (a) Does the fish appear to be at a distance greater than, less than, or equal to $\frac{1}{2}L$ from the front wall? (b) The mirror forms an image of the fish. How far from the front wall is this image located? Express your answer in terms of L. (c) Assume that your answer to Question (b) is a distance D. Does the image of the fish appear to be at a distance greater than, less than, or equal to D from the front wall? (d) Could the image of the fish appear to be in front of the mirror if the index of refraction of water were different than it actually is, and, if so, would the index of refraction have to be greater than or less than its actual value? Explain each of your answers.

Problem The distance between the back and front walls of the aquarium is 40.0 cm. (a) Calculate the apparent distance between the fish and the front wall. (b) Calculate the apparent distance between the image of the fish and the front wall. Verify that your answers are consistent with your answers to the Concept Questions.

* **125.** GO **Concept Questions** (a) For astronomical telescopes that have large angular magnifications, which lens has the greater focal length, the objective or the eyepiece? (b) How is the length L of the telescope related to the focal length f_o of the objective and the focal length f_e of the eyepiece? (c) Three astronomical telescopes have different lengths L, such that $L_A < L_B < L_C$. They have identical eyepieces. Rank the angular magnifications (magnitudes only) of these telescopes in descending order (largest first). For each answer, give your reasoning.

Problem The lengths of the three telescopes are $L_A = 455$ mm, $L_B = 615$ mm, and $L_C = 824$ mm. The focal length of the eyepieces is 3.00 mm for each telescope. Find the angular magnification of each telescope. Be sure that your answers are consistent with your answer to part (c) of the Concept Questions.