5. (II) Suppose you are 90 cm from a plane mirror. What area of the mirror is used to reflect the rays entering one eye from a point on the tip of your nose if your pupil diameter is 5.5 mm?

6. (III) Show that if two plane mirrors meet at an angle ϕ, a single ray reflected successively from both mirrors is deflected through an angle of 2ϕ independent of the incident angle. Assume $\phi < 90°$ and that only two reflections, one from each mirror, take place.

23–3 Spherical Mirrors

7. (I) A solar cooker, really a concave mirror pointed at the Sun, focuses the Sun's rays 18.0 cm in front of the mirror. What is the radius of the spherical surface from which the mirror was made?

8. (I) How far from a concave mirror (radius 23.0 cm) must an object be placed if its image is to be at infinity?

9. (II) If you look at yourself in a shiny Christmas tree ball with a diameter of 9.0 cm when your face is 30.0 cm away from it, where is your image? Is it real or virtual? Is it upright or inverted?

10. (II) A mirror at an amusement park shows an upright image of any person who stands 1.4 m in front of it. If the image is three times the person's height, what is the radius of curvature?

11. (II) A dentist wants a small mirror that, when 2.20 cm from a tooth, will produce a 4.5× upright image. What kind of mirror must be used and what must its radius of curvature be?

12. (II) Some rearview mirrors produce images of cars behind you that are smaller than they would be if the mirror were flat. Are the mirrors concave or convex? What is a mirror's radius of curvature if cars 20.0 m away appear 0.33× their normal size?

13. (II) A luminous object 3.0 mm high is placed 20.0 cm from a convex mirror of radius of curvature 20.0 cm. (*a*) Show by ray tracing that the image is virtual, and estimate the image distance. (*b*) Show that the (negative) image distance can be computed from Eq. 23–2 using a focal length of −10.0 cm. (*c*) Compute the image size, using Eq. 23–3.

14. (II) You are standing 3.0 m from a convex security mirror in a store. You estimate the height of your image to be half of your actual height. Estimate the radius of curvature of the mirror.

15. (II) (*a*) Where should an object be placed in front of a concave mirror so that it produces an image at the same location as the object? (*b*) Is the image real or virtual? (*c*) Is the image inverted or upright? (*d*) What is the magnification of the image?

16. (II) The image of a distant tree is virtual and very small when viewed in a curved mirror. The image appears to be 18.0 cm behind the mirror. What kind of mirror is it, and what is its radius of curvature?

17. (II) Use two different techniques, (*a*) a ray diagram, and (*b*) the mirror equation, to show that the magnitude of the magnification of a concave mirror is less than 1 if the object is beyond the center of curvature C $(d_o > r)$, and is greater than 1 if the object is within C $(d_o < r)$.

18. (II) Show, using a ray diagram, that the magnification m of a convex mirror is $m = -d_i/d_o$, just as for a concave mirror. [*Hint*: consider a ray from the top of the object that reflects at the center of the mirror.]

19. (II) Use ray diagrams to show that the mirror equation, Eq. 23–2, is valid for a convex mirror as long as f is considered negative.

20. (II) The magnification of a convex mirror is +0.65× for objects 2.2 m from the mirror. What is the focal length of this mirror?

21. (III) A 4.5-cm-tall object is placed 28 cm in front of a spherical mirror. It is desired to produce a virtual image that is upright and 3.5 cm tall. (*a*) What type of mirror should be used? (*b*) Where is the image located? (*c*) What is the focal length of the mirror? (*d*) What is the radius of curvature of the mirror?

22. (III) A shaving/makeup mirror is designed to magnify your face by a factor of 1.33 when your face is placed 20.0 cm in front of it. (*a*) What type of mirror is it? (*b*) Describe the type of image that it makes of your face. (*c*) Calculate the required radius of curvature for the mirror.

23–4 Index of Refraction

23. (I) What is the speed of light in (*a*) crown glass, (*b*) Lucite, and (*c*) ethyl alcohol?

24. (I) The speed of light in ice is 2.29×10^8 m/s. What is the index of refraction of ice?

25. (II) The speed of light in a certain substance is 89% of its value in water. What is the index of refraction of this substance?

23–5 Refraction: Snell's Law

26. (I) A flashlight beam strikes the surface of a pane of glass ($n = 1.58$) at a 63° angle to the normal. What is the angle of refraction?

27. (I) A diver shines a flashlight upward from beneath the water at a 42.5° angle to the vertical. At what angle does the light leave the water?

28. (I) A light beam coming from an underwater spotlight exits the water at an angle of 66.0° to the vertical. At what angle of incidence does it hit the air–water interface from below the surface?

29. (I) Rays of the Sun are seen to make a 31.0° angle to the vertical beneath the water. At what angle above the horizon is the Sun?

30. (II) An aquarium filled with water has flat glass sides whose index of refraction is 1.52. A beam of light from outside the aquarium strikes the glass at a 43.5° angle to the perpendicular (Fig. 23–49). What is the angle of this light ray when it enters (*a*) the glass, and then (*b*) the water? (*c*) What would be the refracted angle if the ray entered the water directly?

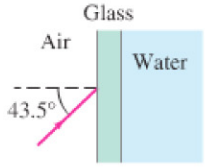

FIGURE 23–49
Problem 30.