83. In a slide or movie projector, the film acts as the object whose image is projected on a screen (Fig. 23–58). If a 105-mm-focal-length lens is to project an image on a screen 8.00 m away, how far from the lens should the slide be? If the slide is 36 mm wide, how wide will the picture be on the screen?

FIGURE 23–58 Problem 83.

84. A 35-mm slide (picture size is actually 24 by 36 mm) is to be projected on a screen 1.80 m by 2.70 m placed 7.50 m from the projector. What focal-length lens should be used if the image is to cover the screen?

85. Show analytically that the image formed by a converging lens is real and inverted if the object is beyond the focal point $(d_o > f)$, and is virtual and upright if the object is within the focal point $(d_o < f)$. Describe the image if the object is itself an image, formed by another lens, so its position is beyond the lens, for which $-d_o > f$, and for which $0 < -d_o < f$.

86. A movie star catches a reporter shooting pictures of her at home. She claims the reporter was trespassing. To prove her point, she gives as evidence the film she seized. Her 1.75-m height is 8.25 mm high on the film, and the focal length of the camera lens was 210 mm. How far away from the subject was the reporter standing?

87. How large is the image of the Sun on film used in a camera with (*a*) a 28-mm-focal-length lens, (*b*) a 50-mm-focal-length lens, and (*c*) a 135-mm-focal-length lens? (*d*) If the 50-mm lens is considered normal for this camera, what relative magnification does each of the other two lenses provide? The Sun has diameter 1.4×10^6 km, and it is 1.5×10^8 km away.

88. (*a*) An object 34.5 cm in front of a certain lens is imaged 8.20 cm in front of that lens (on the same side as the object). What type of lens is this, and what is its focal length? Is the image real or virtual? (*b*) If the image were located, instead, 41.5 cm in front of the lens, what type of lens would it be and what focal length would it have?

89. When an object is placed 60.0 cm from a certain converging lens, it forms a real image. When the object is moved to 40.0 cm from the lens, the image moves 10.0 cm farther from the lens. Find the focal length of this lens.

90. A small object is 25.0 cm from a diverging lens as shown in Fig. 23–59. A converging lens with a focal length of 12.0 cm is 30.0 cm to the right of the diverging lens. The two-lens system forms a real inverted image 17.0 cm to the right of the converging lens. What is the focal length of the diverging lens?

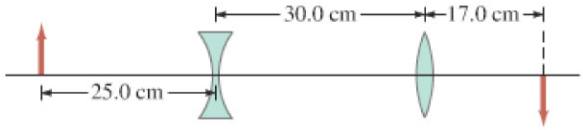

FIGURE 23–59 Problem 90.

91. An object is placed 15 cm from a certain mirror. The image is half the size of the object, inverted, and real. How far is the image from the mirror, and what is the radius of curvature of the mirror?

92. (*a*) Show that the lens equation can be written in the *Newtonian form*

$$xx' = f^2,$$

where x is the distance of the object from the focal point on the front side of the lens, and x' is the distance of the image to the focal point on the other side of the lens. Calculate the location of an image if the object is placed 45.0 cm in front of a convex lens with a focal length f of 32.0 cm using (*b*) the standard form of the thin lens equation, and (*c*) the Newtonian form, stated above.

*** 93.** A converging lens with focal length of 10.0 cm is placed in contact with a diverging lens with a focal length of −20.0 cm. What is the focal length of the combination, and is the combination converging or diverging?

*** 94.** (*a*) Show that if two thin lenses of focal lengths f_1 and f_2 are placed in contact with each other, the focal length of the combination is given by $f_T = f_1 f_2/(f_1 + f_2)$. (*b*) Show that the power P of the combination of two lenses is the sum of their separate powers, $P = P_1 + P_2$.

Answers to Exercises

A: No.
B: Yes; for a plane mirror, $r = \infty$, so $f = \infty$; then Eq. 23–2 gives $1/d_o + 1/d_i = 0$, or $d_i = -d_o$.
C: Toward.
D: None.
E: 1.414.
F: No total internal reflection, $\theta_C > 45°$.
G: Closer to it.
H: (*a*) Virtual; (*b*) virtual.
I: −97.5 cm (that is, 97.5 cm in front of lens).