2. A photographer moves closer to his subject and then refocuses. Does the camera lens move farther away from or closer to the sensor? Explain.

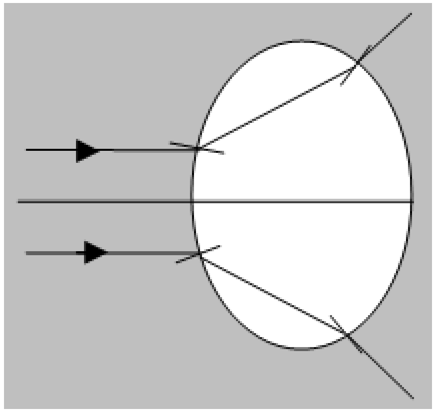
2. The lens moves farther away from the film. When the photographer moves closer to his subject, the object distance decreases. The focal length of the lens does not change, so the image distance must increase, by Eq. 33-2, $\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}$.

7. A thin converging lens is moved closer to a nearby object. Does the real image formed change (*a*) in position, (*b*) in size? If yes, describe how.

7. (*a*) Yes. The image moves farther from the lens.
(*b*) Yes. The image also gets larger.

9. A lens is made of a material with an index of refraction $n = 1.30$. In air, it is a converging lens. Will it still be a converging lens if placed in water? Explain, using a ray diagram.

9. No. The lens will be a diverging lens when placed in water because the index of refraction of the lens is less than the index of refraction of the medium surrounding it. Rays going from water to lens material will bend away from the normal instead of toward the normal, and rays going from the lens back to the water will bend towards the normal.



15. Does the focal length of a lens depend on the fluid in which it is immersed? What about the focal length of a spherical mirror? Explain.

15. Yes. The relative values of the index of refraction of the fluid and the index of refraction of the lens will determine the refraction of light as it passes from the fluid through the lens and back into the fluid. The amount of refraction of light determines the focal length of the lens, so the focal length will change if the lens is immersed in a fluid. No, the image formation of the spherical mirror is determined by reflection, not refraction, and is independent of the medium in which the mirror is immersed.

20. The human eye is much like a camera—yet, when a camera shutter is left open and the camera is moved, the image will be blurred. But when you move your head with your eyes open, you still see clearly. Explain.

20. All light entering the camera lens while the shutter is open contributes to a single picture. If the camera is moved while the shutter is open, the position of the image on the film moves. The new image position overlaps the previous image position, causing a blurry final image. With the eye, new images are continuously being formed by the nervous system, so images do not "build up" on the retina and overlap with each other.

10. (II) (*a*) How far from a 50.0-mm-focal-length lens must an object be placed if its image is to be magnified 2.50× and be real? (*b*) What if the image is to be virtual and magnified 2.50×?

10. (*a*) If the image is real, the focal length must be positive, the image distance must be positive, and the magnification is negative. Thus $d_i = 2.50 d_o$. Use Eq. 33-2.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_o} + \frac{1}{2.50 d_o} = \frac{1}{f} \rightarrow d_o = \left(\frac{3.50}{2.50}\right) f = \left(\frac{3.50}{2.50}\right)(50.0\,\text{mm}) = \boxed{70.0\,\text{mm}}$$

(*b*) If the image is magnified, the lens must have a positive focal length, because negative lenses always form reduced images. Since the image is virtual the magnification is positive. Thus $d_i = -2.50 d_o$. Again use Eq. 33-2.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_o} - \frac{1}{2.5 d_o} = \frac{1}{f} \rightarrow d_o = \left(\frac{1.50}{2.50}\right) f = \left(\frac{1.50}{2.50}\right)(50.0\,\text{mm}) = \boxed{30.0\,\text{mm}}$$

17. (II) In a slide or movie projector, the film acts as the object whose image is projected on a screen (Fig. 33–46). If a 105-mm-focal-length lens is to project an image on a screen 6.50 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?

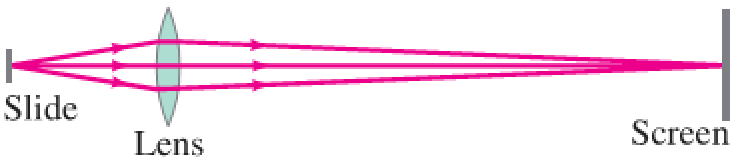


FIGURE 33–46 Slide projector, Problem 17.

17. Find the object distance from Eq. 33-2.

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \rightarrow \frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \rightarrow d_o=\frac{fd_i}{d_i-f}=\frac{(0.105\,\text{m})(6.50\,\text{m})}{6.50\,\text{m}-0.105\,\text{m}}=\boxed{0.107\,\text{m}}$$

Find the size of the image from Eq. 33-3.

$$m=\frac{h_i}{h_o}=-\frac{d_i}{d_o} \rightarrow |h_i|=\frac{d_i}{d_o}h_o=\frac{6.50\,\text{m}}{0.107\,\text{m}}(36\,\text{mm})=2187\,\text{mm}\approx\boxed{2.2\,\text{m}}$$

20. (II) A diverging lens with $f = -33.5\text{ cm}$ is placed 14.0 cm behind a converging lens with $f = 20.0\text{ cm}$. Where will an object at infinity be focused?

20. The first lens is the converging lens. An object at infinity will form an image at the focal point of the converging lens, by Eq. 33-2.

$$\frac{1}{d_{o1}} + \frac{1}{d_{i1}} = \frac{1}{f_1} = \frac{1}{\infty} + \frac{1}{d_{i1}} \rightarrow d_{i1} = f_1 = 20.0\text{cm}$$

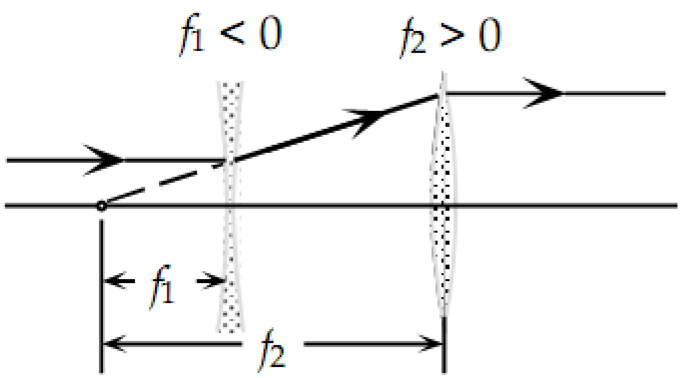
This image is the object for the second lens. Since this image is behind the second lens, the object distance for the second lens is negative, and so $d_{o2} = -6.0\text{cm}$. Again use Eq. 33-2.

$$\frac{1}{d_{o2}} + \frac{1}{d_{i2}} = \frac{1}{f_2} \rightarrow d_{i2} = \frac{d_{o2} f_2}{d_{o2} - f_2} = \frac{(-6.0\text{cm})(-33.5\text{cm})}{(-6.0\text{cm}) - (-33.5\text{cm})} = 7.3\text{cm}$$

Thus the final image is real, **7.3 cm beyond the second lens.**

22. (II) A 34.0-cm-focal-length converging lens is 24.0 cm behind a diverging lens. Parallel light strikes the diverging lens. After passing through the converging lens, the light is again parallel. What is the focal length of the diverging lens? [*Hint*: first draw a ray diagram.]

22. From the ray diagram, the image from the first lens is a virtual image at the focal point of the first lens. This is a real object for the second lens. Since the light is parallel after leaving the second lens, the object for the second lens must be at its focal point. Let the separation of the lenses be ℓ. Note that the focal length of the diverging lens is negative.



$$|f_1| + \ell = f_2 \quad \rightarrow$$

$$|f_1| = f_2 - \ell = 34.0\,\text{cm} - 24.0\,\text{cm} = 10.0\,\text{cm} \quad \rightarrow$$

$$f_1 = \boxed{-10.0\,\text{cm}}$$

41. (II) A person struggles to read by holding a book at arm's length, a distance of 55 cm away. What power of reading glasses should be prescribed for her, assuming they will be placed 2.0 cm from the eye and she wants to read at the "normal" near point of 25 cm?

41. The actual near point of the person is 55 cm. With the lens, an object placed at the normal near point, 25 cm, or 23 cm from the lens, is to produce a virtual image 55 cm from the eye, or 53 cm from the lens. We find the power of the lens from Eqs. 33-1 and 33-3.

$$P = \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{0.23\,\text{m}} + \frac{1}{-0.53\,\text{m}} = \boxed{2.5\,\text{D}}$$

87. A small object is 25.0 cm from a diverging lens as shown in Fig. 33–48. 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?

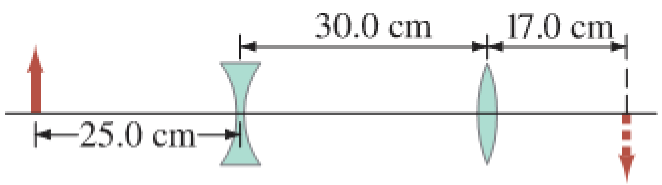


FIGURE 33–48 Problem 87.

87. We use Eq. 33-2 with the final image distance and focal length of the converging lens to determine the location of the object for the second lens. Subtracting this distance from the separation distance between the lenses gives us the image distance from the first lens. Inserting this image distance and object distance into Eq. 33-2, we calculate the focal length of the diverging lens.

$$\frac{1}{d_{o2}} + \frac{1}{d_{i2}} = \frac{1}{f_2} \rightarrow d_{o2} = \frac{d_{i2} f_2}{d_{i2} - f_2} = \frac{(17.0\,\text{cm})(12.0\,\text{cm})}{17.0\,\text{cm} - 12.0\,\text{cm}} = 40.8\,\text{cm}$$

$$d_{i1} = \ell - d_{o2} = 30.0\,\text{cm} - 40.8\,\text{cm} = -10.8\,\text{cm}$$

$$\frac{1}{d_{o1}} + \frac{1}{d_{i1}} = \frac{1}{f_1} \rightarrow f_1 = \frac{d_{i1} d_{o1}}{d_{i1} + d_{o1}} = \frac{(-10.8\,\text{cm})(25.0\,\text{cm})}{-10.8\,\text{cm} + 25.0\,\text{cm}} = \boxed{-19.0\,\text{cm}}$$