***Answer to Essential Question 24.8:*** Yes, there would still be two solutions. One solution involves a real image produced by a converging lens, while the other involves a virtual image produced by a diverging lens.

## *24-9 The Human Eye and the Camera*

There are some interesting parallels between the human eye and a camera. Before continuing, stop and make a list of some of the similarities between the two systems, as well as some of the differences.

An important component of both the eye and a camera is the lens that is used to create a real image. Interestingly, in both systems the image is inverted.

In each case, there is a diaphragm that controls the amount of light that gets through to the lens. In the eye, the pupil plays this role, while the camera shutter does this job in the camera.

Another important component of both systems is the system for recording the focused image. In the eye, this system is the set of rods and cones that cover the retina at the back of the eye. In older cameras, the film does the job of recording the image, while in a digital camera the system is quite similar to that of the eye, with a large number (four million being typical) of tiny light sensors sensing the image.

A key difference between the human eye and the camera is in how the focusing is done. In your own eyes, when you look from one object to another that is a different distance away from you, your eyes adjust to bring the second object into focus. To understand why this adjustment is necessary, considering the thin-lens equation:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} .$$ (Equation 24.7: **The thin-lens equation**)

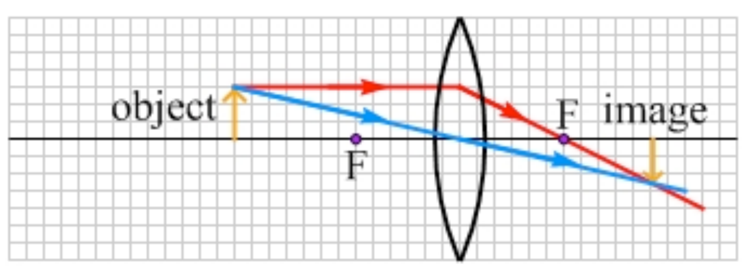
In the human eye, the distance between the lens and retina, which is the image distance $d_i$, is fixed. Changing the object distance thus requires a change in the focal length of the eye to produce a focused image on the retina. This adjustment is done via the ciliary muscles in the eye, which actually change the shape of the lens to change the focal length. This process, known as accommodation, occurs so quickly that we don't even notice it.

In the camera, the lens is generally a solid piece of glass with a fixed focal length. Adjusting the object distance, therefore, requires an adjustment in the image distance (the distance from the lens to the film or light sensors). This is accomplished by moving the lens. The farther the object is from the camera, the closer the lens must be to the film or light sensors.

**EXPLORATION 24.9 – Correcting human vision**

Consider the ray diagram shown in Figure 24.40, in which the object is quite close to the eye.

**Figure 24.40**: A ray diagram for a situation in which you are focusing on an object quite close to you.



**Step 1 –** ***Where is the retina located in Figure 24.40?*** The retina must be where the image is for you to see the focused image. Note that the image is upside down, but when you look at objects you do not see them upside down. The flipping of the image back to upright is accomplished by the image-processing system in your brain.

**Step 2 –** ***If the object in Figure 24.40 is moved farther away, and the eye's focal length is unchanged, where is the focused image? Sketch a new diagram to show this.*** When the object distance increases, and the focal length remains the same, the image distance decreases, as shown in Figure 24.41.

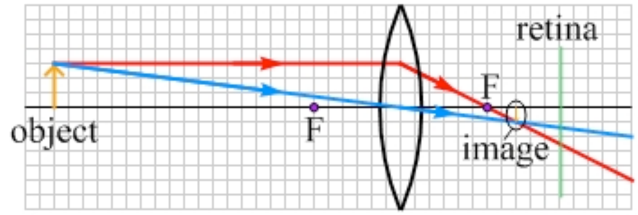



**Figure 24.41**: If the eye's focal length is fixed, moving the object farther from the eye produces a focused image at a point within the eye, and a blurred image on the retina.

**Step 3 –** ***In a normal eye, the shape of the lens is changed so that the image is formed not before the retina, as in Figure 24.41, but on the retina. To accomplish this for the situation shown in Figure 24.41, should the lens be flatter or rounder than the lens that produces the correctly focused image in Figure 24.40, when the object is closer to the eye?*** The lens in Figure 24.41 is doing too much focusing, because it is too round. The ciliary muscles flatten the lens to shift the image position farther from the lens, onto the retina, as shown in Figure 24.42.

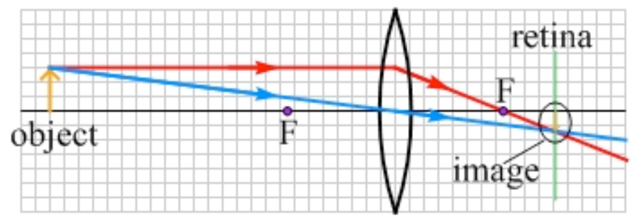



**Figure 24.42**: In a normal eye, when the object is farther from the eye, the curvature of the lens is reduced to focus the image onto the retina.

**Step 4 –** ***In the eye of a near-sighted person (someone who can only focus properly on objects close to them), the lens can not be made flat enough to focus the image of a far-off object on the retina, so a corrective lens is placed in front of the eye. Does a near-sighted person need a diverging lens or a converging lens? Support your answer with a diagram.*** A near-sighted person requires a diverging lens. Before the light from the object reaches the eye, the lens diverges it enough that the eye then deflects the rays to create a focused image on the retina, as shown in Figure 24.43. Another way to understand this is that the diverging lens creates a virtual image of the object close enough to the eye that the near-sighted person can focus on it.

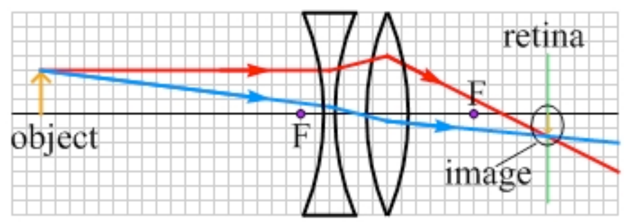



**Figure 24.43**: Placing a diverging lens, of the appropriate shape, in front of the eye of a nearsighted person allows the person to see far-away objects correctly.

**Key ideas for corrective lenses:** In a normal eye, the ciliary muscles adjust the shape of each eye's lens to form images on the retina. In a near-sighted person, the lens cannot be made flat enough to view far-away objects correctly, so a diverging lens is used to correct this deficiency. In a far-sighted person, the lens cannot be made round enough to properly focus on close objects, so the corrective lens is a converging lens. **Related End-of-Chapter Exercises: 29, 63.**

***Essential Question 24.9****:* What if Figure 24.40 represents a camera in which the image is focused on the film? When the object is moved to the position shown in Figure 24.41, what changes in the camera to produce a focused image again? Draw a ray diagram reflecting this change.