

CHAPTER 26: VISION AND OPTICAL INSTRUMENTS

26.1 PHYSICS OF THE EYE

2. Calculate the power of the eye when viewing an object 3.00 m away.

Solution Using the lens-to-retina distance of 2.00 cm and the equation $P = \frac{1}{d_o} + \frac{1}{d_i}$ we can determine the power at an object distance of 3.00 m:

$$P = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{3.00 \text{ m}} + \frac{1}{0.0200 \text{ m}} = \underline{+50.3 \text{ D}}$$

26.2 VISION CORRECTION

10. What was the previous far point of a patient who had laser vision correction that reduced the power of her eye by 7.00 D, producing normal distant vision for her?

Solution Since normal distant vision has a power of 50.0 D ([Example 26.2](#)) and the laser vision correction reduced the power of her eye by 7.00 D, she originally had a power of 57.0 D. We can determine her original far point using

$$P = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow d_o = \left(P - \frac{1}{d_i} \right)^{-1} = \left(57.0 \text{ D} - \frac{1}{0.0200 \text{ m}} \right)^{-1} = \underline{0.143 \text{ m}}$$

Originally, without corrective lenses, she could only see images 14.3 cm (or closer) to her eye.

14. A young woman with normal distant vision has a 10.0% ability to accommodate (that is, increase) the power of her eyes. What is the closest object she can see clearly?

Solution From [Example 26.2](#), the normal power for distant vision is 50.0 D. For this woman,

since she has a 10.0% ability to accommodate, her maximum power is

$$P_{\max} = (1.10)(50.0 \text{ D}) = 55.0 \text{ D}. \text{ Thus using the equation } P = \frac{1}{d_o} + \frac{1}{d_i}, \text{ we can}$$

determine the nearest object she can see clearly since we know the image distance must be the lens-to-retina distance of 2.00cm:

$$P = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow d_o = \left(P - \frac{1}{d_i} \right)^{-1} = \left(55.0 \text{ D} - \frac{1}{0.0200 \text{ m}} \right)^{-1} = 0.200 \text{ m} = \underline{20.0 \text{ cm}}$$

26.5 TELESCOPES

37. *A 7.5× binocular produces an angular magnification of −7.50, acting like a telescope. (Mirrors are used to make the image upright.) If the binoculars have objective lenses with a 75.0 cm focal length, what is the focal length of the eyepiece lenses?*

Solution Using the equation $M = -\frac{f_o}{f_e}$, we can determine the focal length of the eyepiece since we know the magnification and the focal length of the objective:

$$f_e = -\frac{f_o}{M} = -\frac{75.0 \text{ cm}}{-7.50} = \underline{+10.0 \text{ cm}}$$

26.6 ABERRATIONS

39. **Integrated Concepts** (a) *During laser vision correction, a brief burst of 193 nm ultraviolet light is projected onto the cornea of the patient. It makes a spot 1.00 mm in diameter and deposits 0.500 mJ of energy. Calculate the depth of the layer ablated, assuming the corneal tissue has the same properties as water and is initially at 34.0°C. The tissue's temperature is increased to 100°C and evaporated without further temperature increase. (b) Does your answer imply that the shape of the cornea can be finely controlled?*

Solution (a) We can get an expression for the heat transfer in terms of the mass of tissue ablated: $Q = mc\Delta T + mL_v = m(c\Delta T + L_v)$, where the heat capacity is given in Table 14.1, $c = 4186 \text{ J/kg} \cdot ^\circ\text{C}$, and the latent heat of vaporization is given in Table 14.2, $L_v = 2256 \times 10^3 \text{ J/kg}$. Solving for the mass gives:

$$\begin{aligned}
 m &= \frac{Q}{c\Delta T + L_v} \\
 &= \frac{(5.00 \times 10^{-4} \text{ J})}{(4186 \text{ J/kg} \cdot ^\circ\text{C})(100^\circ\text{C} - 34.0^\circ\text{C}) + 2.256 \times 10^6 \text{ J/kg}} = 1.975 \times 10^{-10} \text{ kg}
 \end{aligned}$$

Now, since the corneal tissue has the same properties as water, its density is 1000 kg/m^3 . Since we know the diameter of the spot, we can determine the

thickness of the layer ablated: $\rho = \frac{m}{V} = \frac{m}{\pi r^2 t}$, so that:

$$t = \frac{m}{\pi r^2 \rho} = \frac{1.975 \times 10^{-10} \text{ kg}}{\pi (5.00 \times 10^{-4} \text{ m})^2 (1000 \text{ kg/m}^3)} = 2.515 \times 10^{-7} \text{ m} = \underline{0.251 \text{ } \mu\text{m}}$$

- (b) Yes, this thickness that the shape of the cornea can be very finely controlled, producing normal distant vision in more than 90% of patients.