Portland State University
General Physics Workshop
Problem Set 6

Lens Systems

Equations and Relations:

Index of refraction

$$v = \frac{c}{n}$$

Snell's Law

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Thin Lens Equation

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

Magnification

$$m = -\frac{d_i}{d_o} = \frac{h_i}{h_o}$$

$$\text{f} - \text{number} = \frac{\text{focal length}}{\text{diameter of aperture}} = \frac{f}{D}$$

$$\text{refractive power} = \frac{1}{f}$$

Magnifying Glass – Magnification

$$M = \frac{N}{f} \qquad \text{(image at infinity)}$$

$$M = 1 + \frac{N}{f} \qquad \text{(image at near point, N)}$$

Compound Microscope

$$M_{total} = -\frac{sN}{f_{objective} f_{eyepiece}}$$

Telescope

$$M_{total} = -\frac{f_{objective}}{f_{eyepiece}}$$

$$L = f_{objective} + f_{eyepiece}$$

1. A diverging lens (f=-5 cm) is located 25 cm to the right of a converging lens (f=10 cm). A beetle (length=2 cm) is 30 cm to the left of the converging lens.
   (a) Relative to the diverging lens, where is the image of the beetle?
   (b) What is the magnification of the image?
   (c) What size is the image of the beetle?
   (d) Is the image real or virtual?
   (e) Is it upright or inverted
   (f) Sketch the ray diagram for the two-lens system.

2. The near point of a farsighted person is 65 cm. What power contact lens he must use to correct this problem and be able to read a book at a normal near point of 25 cm?

3. A stamp 1.5 cm x 2 cm is viewed through a magnifying glass with f=10 cm. What is the size of the stamp if the observer's eye is relaxed and has a near point distance of 25 cm?

4. Jenna is farsighted; the nearest object she can see clearly without corrective lenses is 2.0 m away. It is 1.8 cm from the lens of her eye to the retina.
   (a) Sketch a ray diagram to show (qualitatively) what happens when she tries to look at something closer than 2 m, without corrective lenses.
   (b) What should the focal length of her contact lenses be so that she can see objects clearly as close as 20 cm from her eye?

   - *Much of the bending of light rays necessary for human vision occurs at the cornea (at the air-eye interface). The cornea has an index of refraction somewhat greater than that of water.*
     (a) When your eye is submerged in a swimming pool, is the bending of light rays at the cornea greater than, less than, or the same as in air?
     (b) The Central American fish Anableps anableps can see simultaneously above and below water because it swims with its eyes partially extending above the water surface. To provide clear sight in both media, is the radius of curvature of the submerged portion of the cornea greater than, less than, or equal to that of the exposed portion?

5. A nearsighted woman cannot clearly see objects more than 2.0 m away. The distance from the lens of the eye to the retina is 1.8 cm, and the eye's power of accommodation is 4.0 D (the focal length of the cornea-lens system increases by a maximum of 4.0 D over its relaxed focal length when accommodating for nearby objects).
   (a) As an amateur optometrist, what corrective eyeglass lenses would you prescribe to enable her to clearly see distant objects? Assume corrective lenses are 2.0 cm from the eyes.
   (b) Find the nearest object she can see clearly with and without her glasses.

6. A compound microscope has an objective lens of focal length 1.40 cm and an eyepiece with a focal length of 2.20 cm. The objective and the eyepiece are separated by 19.6 cm. The final image is at infinity.
   (a) What is the angular magnification?
   (b) How far from the objective should the object be placed?

7. A telescope of an amateur astronomer has an angular magnification of –200. The eyepiece has a focal length of 5 mm.
   (a) What is the focal length of the objective lens?
   (b) How long is the astronomer's telescope?

   - *In a microscope, the objective lens has a short focal length, whereas in a telescope, the objective lens has a long focal length. Explain the reason for the difference in focal lengths.*

8. A photographer wishes to take a photo of the Eiffel Tower (300 m tall) from across the Seine River, a distance of 500 m from the tower. What focal length lens should she use to get an image that is 20mm high on the film?

    - *In her bag, a photographer is carrying three exchangeable camera lenses with focal lengths of 400, 50, and 28 mm. Which lens should she use for*
      (a) wide angle shots,
      (b) everyday use, and
      (c) telephoto work.

Additional Questions

1. When snorkeling, you wear goggles in order to see clearly. Why is your vision blurry without the goggles?

2. A nearsighted person notices that he is able to see nearby objects more clearly when he is underwater than in air. Why might this be true?

3. For human eyes, about 70% of the refraction occurs at the cornea; less than 25% occurs at the two surfaces of the lens. Why? Is the same thing true for fish eyes?

4. A slide projector forms a real image of the slide on a screen using a converging lens. If the bottom half of the lens is blocked by covering it with opaque tape, does the bottom half of the image disappear, or does the top half disappear, or is the entire image still visible on the screen? If the entire image is visible, is anything different about it?

5. Each retina has a blind spot with no rods or cones, located where the optic nerve leaves the retina. The blind spot is not usually noticed because the brain fills in the missing information. To observe the blind sport, draw a cross and a dot, about 10 cm apart, on a sheet of white paper. Cover your left eye and hold the paper far from your eyes with the dot on the right. Keep you ere focused on the cross as you slowly move the paper toward you face. The dot disappears when the image falls on the blind spot. Continue to move the paper even closer to you eye; you will see the spot again when its image moves off the blind spot.