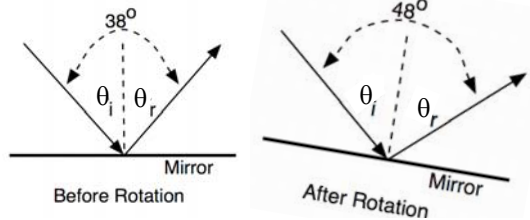


Physics 6C Summer 2006
Homework 3 Solutions by Michael Gary

All problems are from the 2nd edition of Walker. Numerical values are different for each student.

1. **Chapter 26, Problem 1:** A laser beam is reflected by a plane mirror. It is observed that the angle between the incident and reflected beams is 38° . If the mirror is now rotated so that the angle of incidence increases by 5.0° , what is the new angle between the incident and reflected beams?

Solution: $\theta_i = \theta_r$
 $\theta_i + \theta_r = 2\theta_i = 38^\circ + 2(5.0^\circ) = \boxed{48^\circ}$



2. **Chapter 26, Problem 10(a):** How rapidly does the distance between you and your mirror image decrease if you walk directly toward a plane mirror with a speed of 2.4 m/s ?

Solution: The distance decreases at twice the walking rate, since $|d_i| = d_o$ for a plane mirror.

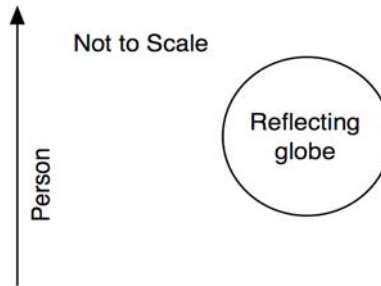
$$2\left(2.4 \frac{\text{m}}{\text{s}}\right) = \boxed{4.8 \text{ m/s}}$$

3. **Chapter 26, Problem 27:** A person 1.6 m tall stands 3.2 m from a reflecting globe in a garden. **(a)** If the diameter of the globe is 18 cm, where is the image of the person, relative to the surface of the globe? **(b)** How large is the person's image? **(c)** Describe the image.

Solution: (a)

$$d_i = \left(\frac{1}{f} - \frac{1}{d_o} \right)^{-1} = \left(-\frac{2}{R} - \frac{1}{d_o} \right)^{-1} = \left(-\frac{4}{D} - \frac{1}{d_o} \right)^{-1} = \left(-\frac{4}{0.18 \text{ m}} - \frac{1}{3.2 \text{ m}} \right)^{-1} = -4.4 \text{ cm}$$

The image is 4.4 cm behind the surface of the globe.



(b) $h_i = mh_o = -\frac{d_i}{d_o} h_o = -\frac{-0.044 \text{ m}}{3.2 \text{ m}} (1.6 \text{ m}) = \boxed{2.2 \text{ cm}}$

(c) virtual, behind the globe, upright

4. **Chapter 26, Problem 29:** The 200-inch-diameter concave mirror of the Hale telescope on Mount Palomar has a focal length of 16.9 m. An astronomer stands 20.0 m in front of this mirror. **(a)** Where is her image located? Is it in front of or behind the mirror? **(b,c)** Is her image real or virtual? Is it upright or inverted? What is the magnification of her image?

Solution: (a)
$$d_i = \left(\frac{1}{f} - \frac{1}{d_o} \right)^{-1} = \left(\frac{1}{16.9 \text{ m}} - \frac{1}{20.0 \text{ m}} \right)^{-1} = 110 \text{ m}$$

The astronomer's image is located 110 m in front of the mirror.

(b) Her image is real because light passes through it.

(c)
$$m = -\frac{d_i}{d_o} = -\frac{1}{20.0 \text{ m}} \left(\frac{1}{16.9 \text{ m}} - \frac{1}{20.0 \text{ m}} \right)^{-1} = \boxed{-5.5}$$
 The image is inverted since $m < 0$

5. **Chapter 26, Problem 37:** Light travels a distance of 0.960 m in 4.00 ns in a given substance. What is the index of refraction of this substance?

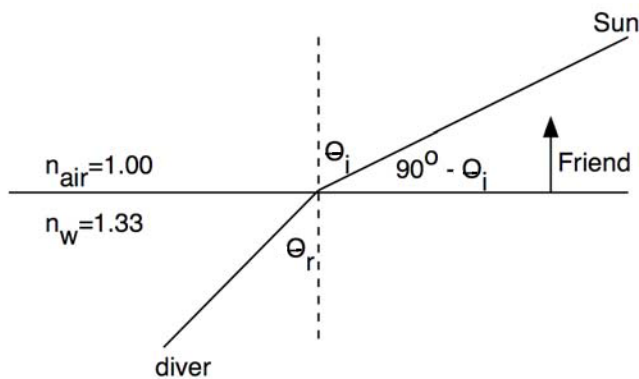
Solution:
$$n = \frac{c}{v} = \frac{3.00 \times 10^8 \frac{\text{m}}{\text{s}}}{\frac{0.960 \text{ m}}{4.00 \times 10^{-9} \text{ s}}} = \boxed{1.25}$$

6. **Chapter 26, Problem 43:** A submerged scuba diver looks up toward the calm surface of a freshwater lake and notes that the Sun appears to be 35° from the vertical. The diver's friend's standing on the shore of the lake. At what angle above the horizon does the friend see the sun?

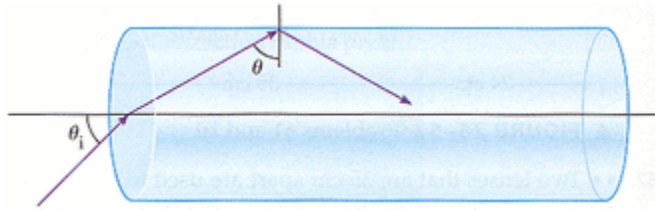
Solution: The diver sees θ_{refr} and the friend sees $90^\circ - \theta_i$.

$$n_{\text{air}} \sin \theta_i = n_{\text{w}} \sin \theta_{\text{refr}}$$

$$90^\circ - \theta_i = 90^\circ - \sin^{-1} \left(\frac{n_{\text{w}}}{n_{\text{air}}} \sin \theta_{\text{refr}} \right) = 90^\circ - \sin^{-1} \left(\frac{1.33}{1.000} \sin 35^\circ \right) = \boxed{40^\circ}$$



7. **Chapter 26, Problem 89:** Figure 26-55 shows a ray of light entering one end of an optical fiber at an angle of incidence $\theta_i = 50.0^\circ$. The index of refraction of the fiber is 1.62. **(a)** Find the angle θ the ray makes with the normal when it reaches the curved surface of the fiber. **(b)** Calculate the critical angle for the optical fiber. **(c)** Show that the internal reflection from the curved surface is total.



$$n_{\text{air}} \sin \theta_i = n \sin(90^\circ - \theta)$$

$$90^\circ - \theta = \sin^{-1} \frac{n_{\text{air}} \sin \theta_i}{n}$$

$$\theta = 90^\circ - \sin^{-1} \frac{(1.00) \sin 50.0^\circ}{1.62}$$

$$= \boxed{61.8^\circ}$$

Solution: a)

$$\sin \theta_c = \frac{n_2}{n_1}$$

$$\theta_c = \sin^{-1} \frac{n_2}{n_1}$$

$$= \sin^{-1} \frac{1.00}{1.62}$$

$$= 38.1^\circ < 61.8^\circ = \theta$$

(b)

(c) $\theta > \theta_c$, so the internal reflection is total.

8. **Chapter 26, Problem 67:** A lens for a 35-mm camera has a focal length given by $f = 45 \text{ mm}$. **(a)** How close to the film should the lens be placed to form a sharp image of an object that is 5.0 m away? **(b)** What is the magnification of the image on the film?

Solution: (a)

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

$$d_i = \left(\frac{1}{f} - \frac{1}{d_o} \right)^{-1} = \left(\frac{1}{0.045 \text{ m}} - \frac{1}{5.0 \text{ m}} \right)^{-1} = \boxed{45 \text{ mm}}$$

(b)

$$m = -\frac{d_i}{d_o} = -\frac{\left(\frac{1}{0.045 \text{ m}} - \frac{1}{5.0 \text{ m}} \right)^{-1}}{5.0 \text{ m}} = \boxed{-0.0091}$$

9. Chapter 26, Problem 76: A friend tells you that when she takes off her eyeglasses and holds them 21 cm above a printed page the image of the print is erect but enlarged to 1.5 times its actual size. (a) What is the focal length of your friend's glasses? (b) Is the image real or virtual? Are the lenses in the glasses concave or convex?

Solution:

(a) First find the image distance: $m = -\frac{d_i}{d_o}$
 $d_i = -md_o = -(1.5)(21 \text{ cm}) = -32 \text{ cm}$

Use this to find the focal length: $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$
 $f = \left(\frac{1}{d_i} + \frac{1}{d_o}\right)^{-1} = \left(\frac{1}{-1.5(21 \text{ cm})} + \frac{1}{21 \text{ cm}}\right)^{-1} = \boxed{63 \text{ cm}}$

(b) Since $d_i < 0$, the image appears on the same side of the lens as the object, which means it is a virtual image. Since $f > 0$, the lenses are convex.

10. Chapter 27, Problem 1: Your friend is 1.6 m tall. (a) When she stands 3.0 m from you, what is the height of her image formed on the retina of your eye? (Consider the eye to consist of a thin lens 1.7 cm from the retina.) (b) What is the height of her image when she is 4.0 m from you?

Solution: (a) $h_i = mh_o = -\frac{d_i h_o}{d_o} = \frac{-(0.017 \text{ m})(1.6 \text{ m})}{3.0 \text{ m}} = -9.1 \text{ mm}$

(b) $h_i = \frac{-(0.017 \text{ m})(1.6 \text{ m})}{4.0 \text{ m}} = -6.8 \text{ mm}$

11. **Chapter 27, Problem 39:** With unaided vision, a librarian can focus only on objects that lie at distances between 5.0 m and 0.50 m. **(a)** Which type of lens (converging or diverging) is needed to correct his nearsightedness? Explain. **(b)** Which type of lens will correct his farsightedness? Explain. **(c)** Find the refractive power needed for each part of the bifocal eyeglass lenses that will give the librarian normal visual acuity from 25 cm out to infinity. (Assume the lenses rest 2.0 cm from his eyes. The 25cm is measured from his eye.)

Solution: (a) A diverging lens will produce an image of a distant object within the librarian's far point.

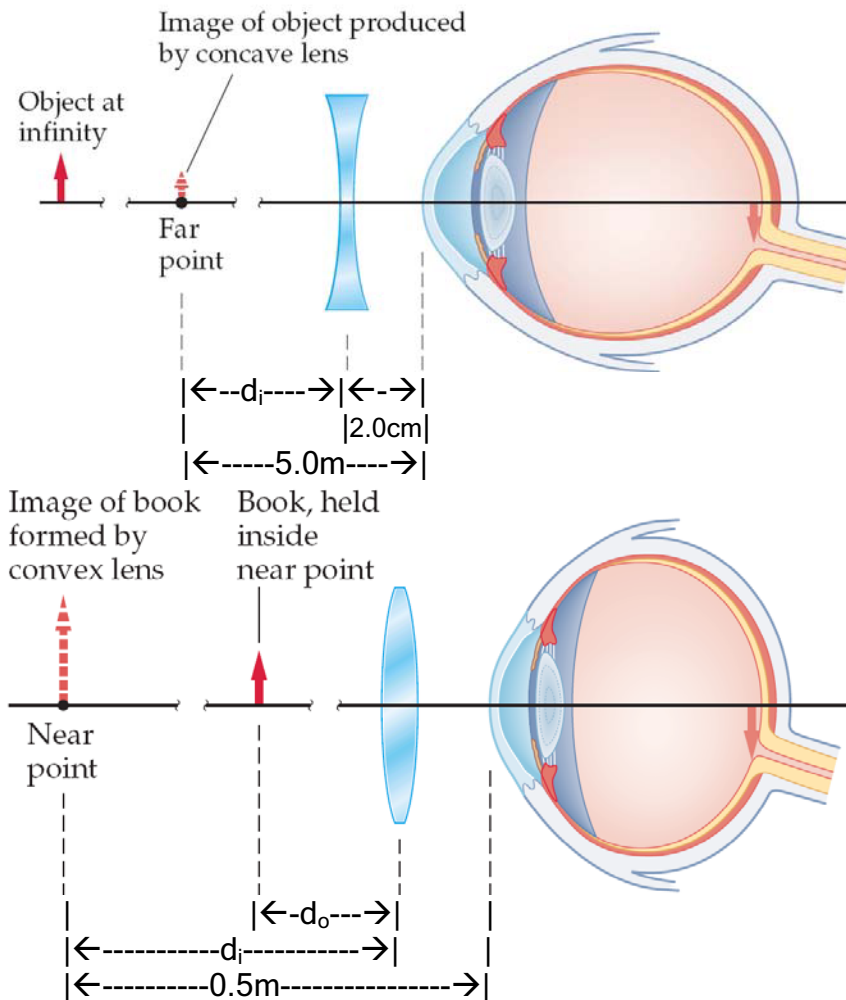
(b) A converging lens will produce an image beyond the librarian's near point of an object that is within the near point.

(c) diverging (distant objects):

$$\text{refractive power} = \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \approx \frac{1}{d_i} = \frac{1}{-(5.0 \text{ m} - 0.020 \text{ m})} = \boxed{-0.20 \text{ diopters}}$$

converging (near objects):

$$\text{refractive power} = \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{0.25 \text{ m} - 0.020 \text{ m}} + \frac{1}{-(0.50 \text{ m} - 0.020 \text{ m})} = \boxed{+2.3 \text{ diopters}}$$



12. **Chapter 27, Problem 46:** A magnifying glass is a single convex lens with a focal length of $f = +12.0 \text{ cm}$ (Assume the person using the magnifying glass has a near point of 25 cm and the magnifying glass is directly in front of the person's eyes.) (a) What is the angular magnification when this lens forms a (virtual) image at $-\infty$? How far from the object should the lens be held? (b) What is the angular magnification when this lens forms a (virtual) image at the person's near point? How far from the object should the lens be held in this case?

Solution: (a)
$$M = \frac{N}{f} = \frac{25 \text{ cm}}{12.0 \text{ cm}} = \boxed{2.1}$$

(b)
$$M = 1 + \frac{N}{f} = 1 + \frac{25 \text{ cm}}{12.0 \text{ cm}} = \boxed{3.1}$$

$$M = 1 + \frac{N}{f} = \frac{N}{d_o}$$

$$d_o = \left(\frac{1}{N} + \frac{1}{f} \right)^{-1} = \left(\frac{1}{25 \text{ cm}} + \frac{1}{12.0 \text{ cm}} \right)^{-1} = \boxed{8.11 \text{ cm}}$$

13. **Chapter 27, Problem 56:** A compound microscope has the objective and eyepiece mounted in a tube that is 18.0 cm long. The focal length of the eyepiece is 2.62 cm, and the near-point distance of the person using the microscope is 25.0 cm. If the person can view the image produced by the microscope with a completely relaxed eye, and the magnification is -4525, what is the focal length of the objective?

Solution:
$$M_{\text{total}} = -\frac{d_i N}{f_{\text{obj}} f_e}$$

$$f_{\text{obj}} = -\frac{d_i N}{M_{\text{total}} f_e} = \frac{(2.62 \text{ cm} - 18.0 \text{ cm})(0.250 \text{ m})}{(-4525)(2.62 \text{ cm})} = \boxed{0.324 \text{ mm}}$$

NOTES FOR PROBLEMS 14, 15, 16:

For telescopes, the correct formula for angular magnification that includes whether the final image is upright or inverted is:

$$M_{\text{tot}} = - f_{\text{objective}} / f_{\text{eyepiece}}$$

As announced in class, the negative sign in this formula is missing from your textbook. **Problem 14** is ignoring the negative sign in the above formula for M_{tot} because it states that the "power (angular magnification)" is positive but it is assuming a standard telescope made from two convex lenses, which produces an inverted image.

Problem 15 is ignoring the negative sign in the above formula for M_{tot} because the type of telescope in this problem produces an inverted image, but WebAssign is interpreting a positive angular size as a correct answer.

Problem 16 was corrected on WebAssign on Thursday July 13 to make the given angular magnification positive (not negative, which is incorrect), because the the type of telescope in this problem produces an upright image.

- 14. Chapter 27, Problem 62: (see note above)** A 42-power refracting telescope has an eyepiece with a focal length of 5.0 cm. How long is the telescope?

Solution: $M_{\text{total}} = \frac{-f_{\text{obj}} - (L - f_e)}{f_e} = -42$

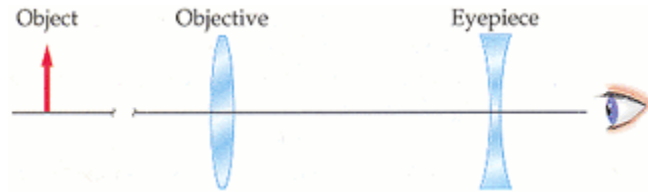
$$L = -M_{\text{total}}f_e + f_e = (5.0 \text{ cm})(1 + 42) = \boxed{2.2 \text{ m}}$$

- 15. Chapter 27, Problem 69: (see note above)** The Moon has an angular size of 0.50° when viewed with unaided vision from Earth. Suppose the Moon is viewed through a telescope with an objective whose focal length is 53 cm and an eyepiece whose focal length is 25 mm. What is the angular size of the Moon as seen through this telescope?

Solution: $M_{\text{total}} = \frac{\theta'}{\theta} = \frac{-f_{\text{obj}}}{f_e}$

$$\theta' = \frac{-f_{\text{obj}}}{f_e} \theta = \frac{-53 \text{ cm}}{2.5 \text{ cm}} (0.50^\circ) = -11^\circ \quad (\text{WebAssign accepts a positive value as correct})$$

16. Chapter 27, Problem 68: (see note above) Galileo's first telescope used a convex objective lens with a focal length $f=1.7\text{m}$ and a concave eyepiece, as shown in Figure 27-23. When this telescope is focused on an infinitely distant object, and produces an infinitely distant image, its angular magnification is $+3.0$ (a) What is the focal length of the eyepiece? (b) How far apart are the two lenses?



Solution: (a) $M_{\text{total}} = -\frac{f_{\text{obj}}}{f_{\text{e}}}$

$$f_{\text{e}} = -\frac{f_{\text{obj}}}{M_{\text{total}}}$$

$$= -\frac{1.7 \text{ m}}{3.0}$$

$$= \boxed{-0.57 \text{ m}}$$

(b) $L = f_{\text{obj}} + f_{\text{e}} = 1.7 \text{ m} - 0.57 \text{ m} = \boxed{1.1 \text{ m}}$