Physics 123, Spring 2009
Homework #7
Due in P123 homework locker 4pm, Friday, March 27, 2009

Feel free to discuss the problems with me and/or each other. Each student must write up his/her own solutions separately.
Unless otherwise indicated, problems are from Giancoli, 4th edition.

Note: If you don't have a copy of volume II of Giancoli, you can find the following questions and problems on the appended pages.

1. Giancoli, chapter 33, **question** 16, page 894.
2. Giancoli, chapter 33, **question** 22, page 894.
3. Giancoli, chapter 33, problem 19, page 895.
4. Giancoli, chapter 33, problem 41, page 896.
5. Giancoli, chapter 33, problem 44, page 896.
6. Giancoli, chapter 33, problem 49, page 896.

16. An underwater lens consists of a carefully shaped thin-walled plastic container filled with air. What shape should it have in order to be (*a*) converging (*b*) diverging? Use ray diagrams to support your answer.
17. Consider two converging lenses separated by some distance. An object is placed so that the image from the first lens lies exactly at the focal point of the second lens. Will this combination produce an image? If so, where? If not, why not?
18. Will a nearsighted person who wears corrective lenses in her glasses be able to see clearly underwater when wearing those glasses? Use a diagram to show why or why not.
19. You can tell whether people are nearsighted or farsighted by looking at the width of their face through their glasses. If a person's face appears narrower through the glasses, (Fig. 33–45), is the person farsighted or nearsighted?

FIGURE 33–45
Question 19.

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.
21. In attempting to discern distant details, people will sometimes squint. Why does this help?
22. Is the image formed on the retina of the human eye upright or inverted? Discuss the implications of this for our perception of objects.
23. Reading glasses use converging lenses. A simple magnifier is also a converging lens. Are reading glasses therefore magnifiers? Discuss the similarities and differences between converging lenses as used for these two different purposes.
24. Why must a camera lens be moved farther from the film to focus on a closer object?
*25. Spherical aberration in a thin lens is minimized if rays are bent equally by the two surfaces. If a planoconvex lens is used to form a real image of an object at infinity, which surface should face the object? Use ray diagrams to show why.
*26. For both converging and diverging lenses, discuss how the focal length for red light differs from that for violet light.

Problems

33–1 and 33–2 Thin Lenses

1. (I) A sharp image is located 373 mm behind a 215-mm-focal-length converging lens. Find the object distance (*a*) using a ray diagram, (*b*) by calculation.
2. (I) Sunlight is observed to focus at a point 18.5 cm behind a lens. (*a*) What kind of lens is it? (*b*) What is its power in diopters?
3. (I) (*a*) What is the power of a 23.5-cm-focal-length lens? (*b*) What is the focal length of a −6.75-D lens? Are these lenses converging or diverging?
4. (II) A certain lens focuses an object 1.85 m away as an image 48.3 cm on the other side of the lens. What type of lens is it and what is its focal length? Is the image real or virtual?
5. (II) A 105-mm-focal-length lens is used to focus an image on the sensor of a camera. The maximum distance allowed between the lens and the sensor plane is 132 mm. (*a*) How far ahead of the sensor should the lens be if the object to be photographed is 10.0 m away? (*b*) 3.0 m away? (*c*) 1.0 m away? (*d*) What is the closest object this lens could photograph sharply?
6. (II) A stamp collector uses a converging lens with focal length 28 cm to view a stamp 18 cm in front of the lens. (*a*) Where is the image located? (*b*) What is the magnification?
7. (II) It is desired to magnify reading material by a factor of 2.5× when a book is placed 9.0 cm behind a lens. (*a*) Draw a ray diagram and describe the type of image this would be. (*b*) What type of lens is needed? (*c*) What is the power of the lens in diopters?
8. (II) A −8.00-D lens is held 12.5 cm from an ant 1.00 mm high. Describe the position, type, and height of the image.
9. (II) An object is located 1.50 m from an 8.0-D lens. By how much does the image move if the object is moved (*a*) 0.90 m closer to the lens, and (*b*) 0.90 m farther from the lens?
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×?
11. (II) How far from a converging lens with a focal length of 25 cm should an object be placed to produce a real image which is the same size as the object?
12. (II) (*a*) A 2.80-cm-high insect is 1.30 m from a 135-mm-focal-length lens. Where is the image, how high is it, and what type is it? (*b*) What if $f = -135$ mm?
13. (II) A bright object and a viewing screen are separated by a distance of 86.0 cm. At what location(s) between the object and the screen should a lens of focal length 16.0 cm be placed in order to produce a sharp image on the screen? [*Hint*: first draw a diagram.]
14. (II) How far apart are an object and an image formed by an 85-cm-focal-length converging lens if the image is 2.95× larger than the object and is real?
15. (II) Show analytically that the image formed by a converging lens (*a*) is real and inverted if the object is beyond the focal point ($d_o > f$), and (*b*) is virtual and upright if the object is within the focal point ($d_o < f$). Next, describe the image if the object is itself an image (formed by another lens), and its position is on the opposite side of the lens from the incoming light, (*c*) for $-d_o > f$, and (*d*) for $0 < -d_o < f$.

16. (II) A converging lens has focal length f. When an object is placed a distance $d_o > f$ from this lens, a real image with magnification m is formed. (*a*) Show that $m = f/(f - d_o)$. (*b*) Sketch m vs. d_o over the range $f < d_o < \infty$ where $f =$ 0.45 cm. (*c*) For what value of d_o will the real image have the same (lateral) size as the object? (*d*) To obtain a real image that is much larger than the object, in what general region should the object be placed relative to the lens?

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.

18. (III) A bright object is placed on one side of a converging lens of focal length f, and a white screen for viewing the image is on the opposite side. The distance $d_T = d_i + d_o$ between the object and the screen is kept fixed, but the lens can be moved. (*a*) Show that if $d_T > 4f$, there will be two positions where the lens can be placed and a sharp image will be produced on the screen. (*b*) If $d_T < 4f$, show that there will be no lens position where a sharp image is formed. (*c*) Determine a formula for the distance between the two lens positions in part (*a*), and the ratio of the image sizes.

19. (III) (*a*) Show that the lens equation can be written in the *Newtonian form*:

$$xx' = f^2,$$

where x is the distance of the object from the focal point on the front side of the lens, and x' is the distance of the image to the focal point on the other side of the lens. Calculate the location of an image if the object is placed 48.0 cm in front of a convex lens with a focal length of 38.0 cm using (*b*) the standard form of the thin lens formula, and (*c*) the Newtonian form, derived above.

33–3 Lens Combinations

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

21. (II) Two 25.0-cm-focal-length converging lenses are placed 16.5 cm apart. An object is placed 35.0 cm in front of one lens. Where will the final image formed by the second lens be located? What is the total magnification?

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.]

23. (II) The two converging lenses of Example 33–5 are now placed only 20.0 cm apart. The object is still 60.0 cm in front of the first lens as in Fig. 33–14. In this case, determine (*a*) the position of the final image, and (*b*) the overall magnification. (*c*) Sketch the ray diagram for this system.

24. (II) A diverging lens with a focal length of −14 cm is placed 12 cm to the right of a converging lens with a focal length of 18 cm. An object is placed 33 cm to the left of the converging lens. (*a*) Where will the final image be located? (*b*) Where will the image be if the diverging lens is 38 cm from the converging lens?

25. (II) Two lenses, one converging with focal length 20.0 cm and one diverging with focal length −10.0 cm, are placed 25.0 cm apart. An object is placed 60.0 cm in front of the converging lens. Determine (*a*) the position and (*b*) the magnification of the final image formed. (*c*) Sketch a ray diagram for this system.

26. (II) A diverging lens is placed next to a converging lens of focal length f_C, as in Fig. 33–15. If f_T represents the focal length of the combination, show that the focal length of the diverging lens, f_D, is given by

$$\frac{1}{f_D} = \frac{1}{f_T} - \frac{1}{f_C}.$$

27. (II) A lighted candle is placed 36 cm in front of a converging lens of focal length $f_1 = 13$ cm, which in turn is 56 cm in front of another converging lens of focal length $f_2 = 16$ cm (see Fig. 33–47). (*a*) Draw a ray diagram and estimate the location and the relative size of the final image. (*b*) Calculate the position and relative size of the final image.

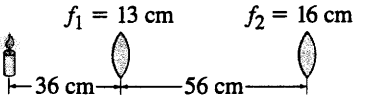

FIGURE 33–47 Problem 27.

*33–4 Lensmaker's Equation

*28. (I) A double concave lens has surface radii of 33.4 cm and 28.8 cm. What is the focal length if $n = 1.58$?

*29. (I) Both surfaces of a double convex lens have radii of 31.4 cm. If the focal length is 28.9 cm, what is the index of refraction of the lens material?

*30. (I) Show that if the lens of Example 33–7 is reversed, the focal length is unchanged.

*31. (I) A planoconvex lens (Fig. 33–2a) is to have a focal length of 18.7 cm. If made from fused quartz, what must be the radius of curvature of the convex surface?

*32. (II) An object is placed 90.0 cm from a glass lens ($n = 1.52$) with one concave surface of radius 22.0 cm and one convex surface of radius 18.5 cm. Where is the final image? What is the magnification?

*33. (II) A prescription for a corrective lens calls for +3.50 diopters. The lensmaker grinds the lens from a "blank" with $n = 1.56$ and convex front surface of radius of curvature of 30.0 cm. What should be the radius of curvature of the other surface?

33–5 Camera

34. (I) A properly exposed photograph is taken at $f/16$ and $\frac{1}{120}$ s. What lens opening is required if the shutter speed is $\frac{1}{1000}$ s?

35. (I) A television camera lens has a 17-cm focal length and a lens diameter of 6.0 cm. What is its f-number?

36. (II) A "pinhole" camera uses a tiny pinhole instead of a lens. Show, using ray diagrams, how reasonably sharp images can be formed using such a pinhole camera. In particular, consider two point objects 2.0 cm apart that are 1.0 m from a 1.0-mm-diameter pinhole. Show that on a piece of film 7.0 cm behind the pinhole the two objects produce two separate circles that do not overlap.

37. (II) Suppose that a correct exposure is $\frac{1}{250}$ s at $f/11$. Under the same conditions, what exposure time would be needed for a pinhole camera (Problem 36) if the pinhole diameter is 1.0 mm and the film is 7.0 cm from the hole?

38. (II) Human vision normally covers an angle of about 40° horizontally. A "normal" camera lens then is defined as follows: When focused on a distant horizontal object which subtends an angle of 40°, the lens produces an image that extends across the full horizontal extent of the camera's light-recording medium (film or electronic sensor). Determine the focal length f of the "normal" lens for the following types of cameras: (*a*) a 35-mm camera that records images on film 36 mm wide; (*b*) a digital camera that records images on a charge-coupled device (CCD) 1.00 cm wide.

39. (II) A nature photographer wishes to photograph a 38-m tall tree from a distance of 65 m. What focal-length lens should be used if the image is to fill the 24-mm height of the sensor?

33–6 Eye and Corrective Lenses

40. (I) A human eyeball is about 2.0 cm long and the pupil has a maximum diameter of about 8.0 mm. What is the "speed" of this lens?

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?

42. (II) Reading glasses of what power are needed for a person whose near point is 105 cm, so that he can read a computer screen at 55 cm? Assume a lens–eye distance of 1.8 cm.

43. (II) If the nearsighted person in Example 33–13 wore contact lenses corrected for the far point ($= \infty$), what would be the near point? Would glasses be better in this case?

44. (II) An eye is corrected by a -4.50-D lens, 2.0 cm from the eye. (*a*) Is this eye near- or farsighted? (*b*) What is this eye's far point without glasses?

45. (II) A person's right eye can see objects clearly only if they are between 25 cm and 78 cm away. (*a*) What power of contact lens is required so that objects far away are sharp? (*b*) What will be the near point with the lens in place?

46. (II) A person has a far point of 14 cm. What power glasses would correct this vision if the glasses were placed 2.0 cm from the eye? What power contact lenses, placed on the eye, would the person need?

47. (II) One lens of a nearsighted person's eyeglasses has a focal length of -23.0 cm and the lens is 1.8 cm from the eye. If the person switches to contact lenses placed directly on the eye, what should be the focal length of the corresponding contact lens?

48. (II) What is the focal length of the eye lens system when viewing an object (*a*) at infinity, and (*b*) 38 cm from the eye? Assume that the lens–retina distance is 2.0 cm.

49. (II) A nearsighted person has near and far points of 10.6 and 20.0 cm respectively. If she puts on contact lenses with power $P = -4.00$ D, what are her new near and far points?

50. (II) The closely packed cones in the fovea of the eye have a diameter of about 2 μm. For the eye to discern two images on the fovea as distinct, assume that the images must be separated by at least one cone that is not excited. If these images are of two point-like objects at the eye's 25-cm near point, how far apart are these barely resolvable objects? Assume the diameter of the eye (cornea-to-fovea distance) is 2.0 cm.

33–7 Magnifying Glass

51. (I) What is the focal length of a magnifying glass of 3.8× magnification for a relaxed normal eye?

52. (I) What is the magnification of a lens used with a relaxed eye if its focal length is 13 cm?

53. (I) A magnifier is rated at 3.0× for a normal eye focusing on an image at the near point. (*a*) What is its focal length? (*b*) What is its focal length if the 3.0× refers to a relaxed eye?

54. (II) Sherlock Holmes is using an 8.80-cm-focal-length lens as his magnifying glass. To obtain maximum magnification, where must the object be placed (assume a normal eye), and what will be the magnification?

55. (II) A small insect is placed 5.85 cm from a +6.00-cm-focal-length lens. Calculate (*a*) the position of the image, and (*b*) the angular magnification.

56. (II) A 3.40-mm-wide bolt is viewed with a 9.60-cm-focal-length lens. A normal eye views the image at its near point. Calculate (*a*) the angular magnification, (*b*) the width of the image, and (*c*) the object distance from the lens.

57. (II) A magnifying glass with a focal length of 9.5 cm is used to read print placed at a distance of 8.3 cm. Calculate (*a*) the position of the image; (*b*) the angular magnification.

58. (II) A magnifying glass is rated at 3.0× for a normal eye that is relaxed. What would be the magnification for a relaxed eye whose near point is (*a*) 65 cm, and (*b*) 17 cm? Explain the differences.

59. (II) A converging lens of focal length $f = 12$ cm is being used by a writer as a magnifying glass to read some fine print on his book contract. Initially, the writer holds the lens above the fine print so that its image is at infinity. To get a better look, he then moves the lens so that the image is at his 25-cm near point. How far, and in what direction (toward or away from the fine print) did the writer move the lens? Assume the writer's eye is adjusted to remain always very near the magnifying glass.

33–8 Telescopes

60. (I) What is the magnification of an astronomical telescope whose objective lens has a focal length of 78 cm, and whose eyepiece has a focal length of 2.8 cm? What is the overall length of the telescope when adjusted for a relaxed eye?

61. (I) The overall magnification of an astronomical telescope is desired to be 35×. If an objective of 88 cm focal length is used, what must be the focal length of the eyepiece? What is the overall length of the telescope when adjusted for use by the relaxed eye?

62. (II) A 7.0× binocular has 3.0-cm-focal-length eyepieces. What is the focal length of the objective lenses?

63. (II) An astronomical telescope has an objective with focal length 75 cm and a +35 D eyepiece. What is the total magnification?

64. (II) An astronomical telescope has its two lenses spaced 78.0 cm apart. If the objective lens has a focal length of 75.5 cm, what is the magnification of this telescope? Assume a relaxed eye.

65. (II) A Galilean telescope adjusted for a relaxed eye is 33.8 cm long. If the objective lens has a focal length of 36.0 cm, what is the magnification?