Chapter 23

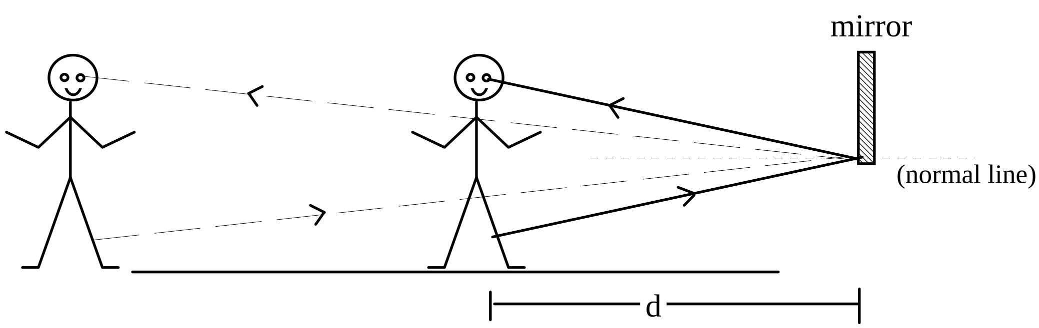
A Good Thing To Know

Equation 23-3 will later be defined as the Lens Equation. It can be manipulated Using Algebraic Wizardry to solve for focal point (f), image distance (di) or object distance (do) as follows:

$$f = \frac{d_i d_o}{d_i + d_o} \qquad d_i = \frac{f d_o}{d_o - f} \qquad d_o = \frac{f d_i}{d_i - f}$$

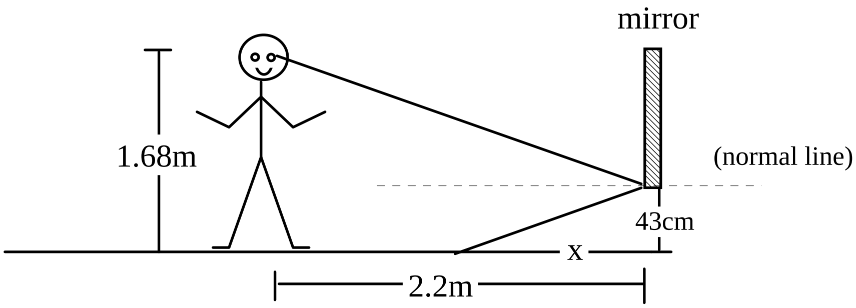
1. For a flat mirror, the image appears to be an equal distance behind the mirror. How far is that total distance from the actual object?

2.



He can't see his feet if he stands at distance d, will it help to back up?

4.



Since the angle of incidence = the angle of reflection, you can have two similar right triangles. Solve for x.

7. Rays from the sun hit the Earth in parallel lines. The image will be at the focal point.

8. To produce an image infinitely far away, place the object at the focal point.
Now do = f. Solve for do.

To solve this problem you also need the image distance so you can use the lens equation and solve for the focal length. The radius of curvature is just 2x the focal length.

9. A shiny Christmas tree ball will act as a diverging (convex) mirror. See Example 23-6 on page 695.

10. See Example 23-3 on page 640.

11. The image is upright and magnified – that tells you what kind of a mirror it is. You have been given the object distance and the magnification. To find the image distance, use the simple proportion on page 638. Magnification = hi/ho = di/do. Solve for di using the magnification equation, then plug that into the lens equation to solve for focal length and then radius of curvature.

12. You are given object height, object distance and radius. From the radius, find focal length. From focal length and object distance, find image distance. Use the ratio of image distance to object distance to find magnification, and magnification with object height to find image height.

13. a) See rules for ray diagrams on page 637.
    b) See A Good Thing To Know on page 75 of this book. Use f = -10cm and solve for di.
    c) Equation 23-3 is on page 638.

15. a) If do = di, substitute do for di in the focal length equation on page 75 of this book and solve for f.
    b) If the image from a mirror occurs on the same side as the object, it is real.
    c) If M is (+) the image is right side up. If M is (-) the image is upside down.
    d) See equation 23-3 on page 638.

16. If the image is very small, the object distance is taken to be at infinity and the image distance is the same as the focal distance.

17. See rules for ray diagrams on page 637.

21. a) Only one kind of mirror will produce an image that is virtual and smaller than the object.
    b) Use the equation for image distance from page 75 of this book.
    c) Use the focal length equation on page 75 of this book.
    d) The radius of curvature is 2x the focal length.

23. You will need equation 23-4 and Table 23-1 on page 642

25. Use 0.89c for the velocity of light in the certain substance.
    You will need equation 23-4 and Table 23-1 on page 642. Then solve for n.

24. You will need to use Table 23-1 on page 642

26. Use Snell's Law on page 643 to solve this one. See Table 23-1 on page 642 for indices of refraction.

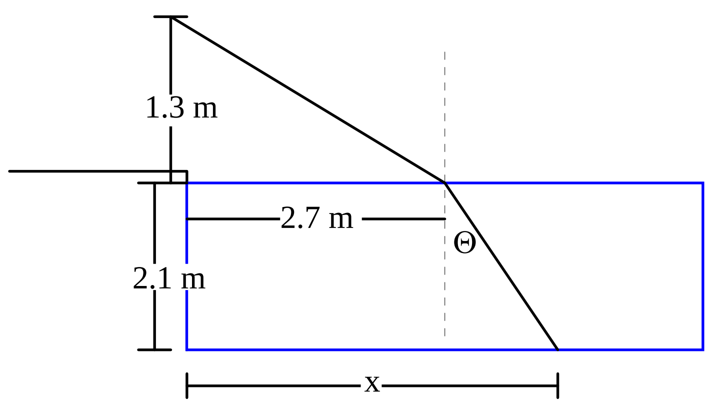
27. Use Snell's Law on page 643 to solve this one. n_1 will be the index of refraction of water. See Table 23-1 on page 696 for indices of refraction.

28. Use Snell's Law on page 643 to solve this one. See Table 23-1 on page 642 for indices of refraction.

29. Use Snell's Law on page 643 to solve this one. n_1 will be the index of refraction of water. See Table 23-1 on page 642 for indices of refraction.

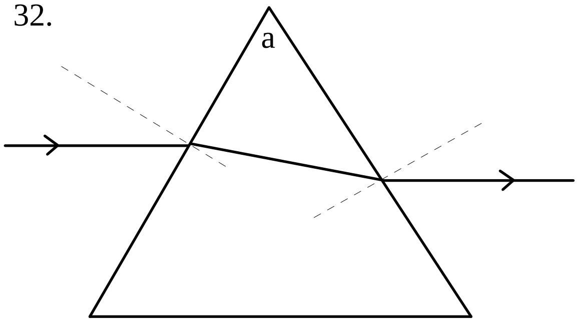
30. a) Find the refracted when n_1 is air and n_2 is glass.
    b) Use the refracted angle from (a) as your incident angle and solve for the new refracted angle as the light passes from glass to water.
    c) Find the refracted angle when n_1 is air and n_2 is water.

31. Use the Pythagorean theorem to get the angle of incidence – but remember the angle of incidence is between the normal and the ray – not the surface of the water and the ray. From that you can find the angle of refraction.
    Make a right triangle with the vertical leg formed by the depth of the pool Θ formed by the angle of refraction.
    Use trigonometry to calculate the base of the triangle and add that to the 2.7 m out from the side that the beam entered the water.



a) Use Snell's Law to find the angle of refraction when the ray goes from air to glass.
b) Use Snell's Law and the angle of refraction from (a) as the incident angle to find the refraction from glass to water.
c) Repeat (a) going from air to water.

32.



Use Snell's Law to calculate the first angle of refraction.

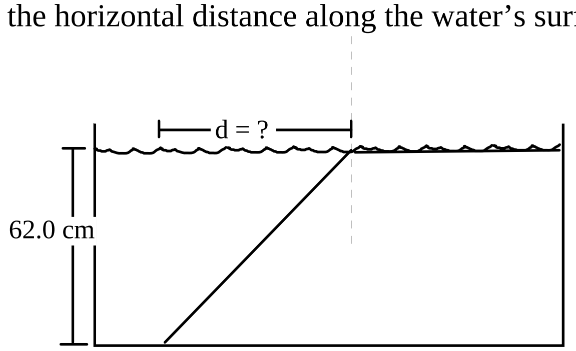
It is an equilateral triangle, so angle a must be 60^{o}.

Use the complement of the refracted angle and your knowledge of triangles to find the third angle o the triangle formed. It's complement is the inside incident angle. Now use Snell's Law again to find the refracted angle outside the glass.

The indices of refraction for glass and air can be found in Table 23-1 on page 642

36. You need Table 23-1 on page 642 and equations for critical angle found on page 642.

38. Find the critical angle for water in air. One side of the triangle is the depth of the pool. They are asking for the horizontal distance along the water's surface to the normal.



43. You have image distance and focal length.
a) Make a ray diagram. b) Use the lens equation and solve for object distance.

44. If it makes sunlight focus to a point – you know what kind of lens it is.

45. Both di and do are positive which means the image can be focused on a screen. Calculate the focal length (see page 75 of this book) and answer both questions.

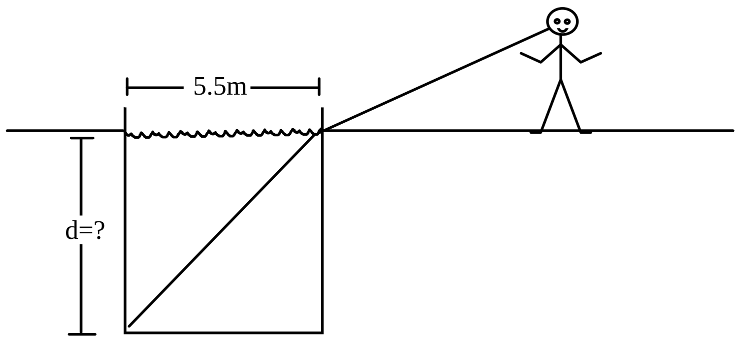
46. See page 648 and equation 23-7

47. You have focal length and do. Use the lens equation to solve for di. Once you have do and di, solve for M.

53. a) Using the magnification, find the image distance in terms of the object distance. Use that value (some factor times do) as di, plug your variables into the lens equation and solve for do. WATCH YOUR SIGNS
b) Same as (a) and WATCH YOUR SIGNS

55. a) You have object height, object distance and focal length. List your variables and solve for image distance using the lens equation. From that you can find magnification and then image height.
The sign (+ or -) on your image distance will tell you whether it is real or virtual.
b) Same as (a), they've just given you a different value for focal length.

73. They gave you the angle to the horizontal and the angle used in Snell's Law is the one measured relative to the normal. Make the correction and solve for the refracted angle. You are given the width of the pool, find the depth using the diagram below.



74. Use the equation for critical angle and solve for the index of refraction for the plastic. Once you have that you can solve for the critical angle between that plastic and water. Table 23-1 on page 642 will give you the index of refraction for water and air.

78. Since $M = \frac{-di}{do}$ and the object is real, calculate do relative to di when di is negative, and do relative to di when di is positive.