Physics 4C
Chapter 34: Images

". . . Everything can be taken from a man but one thing; the last of the human freedoms – to choose one's attitude in any given set of circumstances, to choose one's own way."
– Victor E. Frankl

"It's not what happens to you that determines how far you will go in life; it is how you handle what happens to you." – Zig Ziglar

"Remember happiness doesn't depend upon who you are or what you have; it depends solely on what you think." – Dale Carnegie

"Your thoughts are the architects of your destiny." – David O. McKay

Reading: pages 924 – 949

Outline:

⇒ real and virtual images (PowerPoint)
  mirages
⇒ plane mirrors
⇒ spherical mirrors
  concave and convex mirrors
  focal point and focal length
⇒ images from spherical mirrors
  mirror equation
  magnification equation
  ray tracing
⇒ spherical refracting surfaces (read on your own)
⇒ thin lenses
  lens maker's equation
  ray tracing
  two-lens systems
⇒ optical instruments (read on your own)
  magnifying lens
  compound microscope
  refracting telescope
⇒ proofs of equations (read on your own)

Problem Solving Techniques

You should be able to calculate the image position for an object in front of a plane or spherical mirror. Use the mirror equations: $i = -p$ for a plane mirror and $(1/p) + (1/i) = (1/f)$, where $f = ½ R$ for a spherical mirror. Be careful about the signs of the various quantities. Be sure you know the location of the image formed by a plane mirror and how to tell if the image is visible to an observer at a given location. Recall that the lateral magnification is given by $m = - i/p$ and that the lateral size h' of the image is related to the lateral size h of the object by $h' = mh$. Know how to interpret signs.

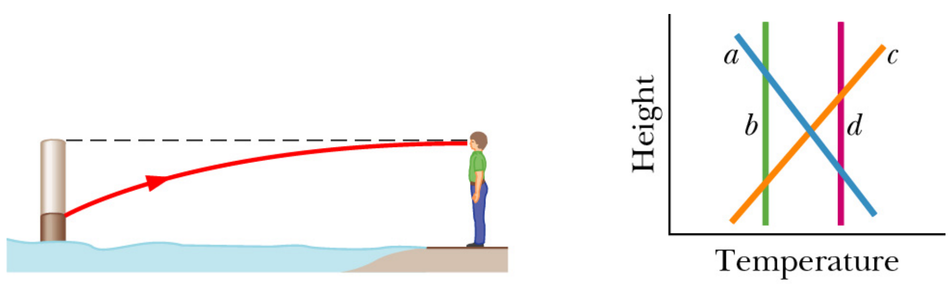
You should know how to find the image formed by a spherical refracting surface and by a lens. If the incoming rays make small angles with the central axis, use $(n_1/p) + (n_2/i) = (n_2 - n_1)/r$ for a single surface and $(1/p) + (1/i) = (1/f)$ for a thin lens in air. You should also know how to compute the focal length, given the radii of the two surfaces of a lens. See Eq. 34-10.

You should understand compound lens systems, such as microscopes and telescopes. Be sure you can calculate the angular magnification for each of these instruments.

Questions and Example Problems from Chapter 34

Question 1

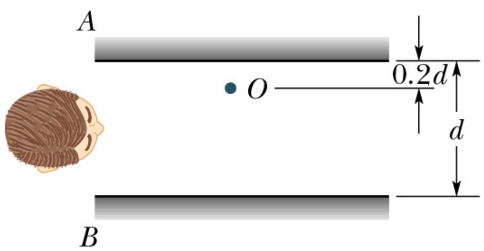
Lake monsters, mermen, and mermaids have long been "sighted" by observers located either on a shore or on a low deck of a ship. From such a low point, an observer can intercept rays of light that leave a floating object (say, a log or a porpoise) and bend slightly back downward toward the observer (one such refracted ray, exaggerated, is shown in figure a below). The observer then perceives the object as being elongated upward from the water (and probably oscillating because of air turbulence) in a mirage that might easily resemble one of the fabled creatures. Figure b below gives several plots of height from the water surface versus air temperature. Which one of the plots best illustrates the air-temperature conditions that can bend the light rays so as to create this mirage?



(a) (b)

Question 2

In the figure below you look into a system of two vertical parallel mirrors A and B separated by distance d. A grinning gargoyle is perched at point O, a distance 0.2d from mirror A. Each mirror produces a first (least deep) image of the gargoyle. Then each mirror produces a second image with the object being the first image in the opposite mirror. Then each mirror produces a third image with the object being the second image in the opposite mirror, and so on—you might see hundreds of grinning gargoyle images. How deep behind mirror A are the first, second, and third images in mirror A?



Problem 1

You look through a camera toward an image of a hummingbird in a plane mirror. The camera is 4.30 m in front of the mirror. The bird is at camera level, 5.00 m to your right and 3.30 m from the mirror. What is the distance between the camera and the apparent position of the bird's image in the mirror?

Problem 2

The image behind a convex mirror (radius of curvature = 68 cm) is located 22 cm from the mirror. (a) Where is the object located and (b) what is the magnification of the mirror? Determine whether the image is (c) upright or inverted and (d) larger or smaller than the object.

Problem 3

A small cup of green tea is positioned on the central axis of a spherical mirror. The lateral magnification of the cup is +0.250, and the distance between the mirror and its focal point is 2.00 cm. (a) What is the distance between the mirror and the image it produces? (b) Is the focal length positive or negative? (c) Is the image real or virtual?

Problem 4

A concave mirror has a radius of curvature of 24 cm. How far is an object from the mirror if an image is formed that is (a) virtual and 3.0 times the size of the object, (b) real and 3.0 times the size of the object?

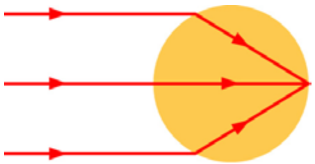
Problem 5

Fill in the table below, each row of which refers to a different combination of an object and either a plane mirror, a spherical convex mirror, or a spherical concave mirror. Distances are in centimeters. If a number lacks a sign, find the sign.

Type	*f*	*r*	*i*	*p*	*m*	Real Image?	Inverted Image?
(a)				+10	+1.0	No	
(b)	+20			+30			
(c) Convex		40	4.0				
(d)				+24	0.50		Yes

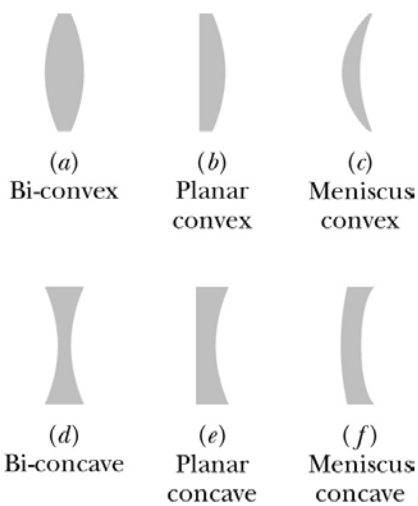
Problem 6

A beam of parallel light rays from a laser is incident on a solid transparent sphere of index of refraction n (see the figure below). (a) If a point image is produced at the back of the sphere, what is the index of refraction of the sphere? (b) What index of refraction, if any, will produce a point image at the center of the sphere?



Problem 7

You have a supply of flat glass (n = 1.5) and a lens-grinding machine that can be set to grind a radius of curvature of either 40 cm or 60 cm. You are asked to prepare a set of six lenses like those shown below. What will be the focal length of each lens? (Note: Where you have a choice of radii of curvature, select the smaller one.)

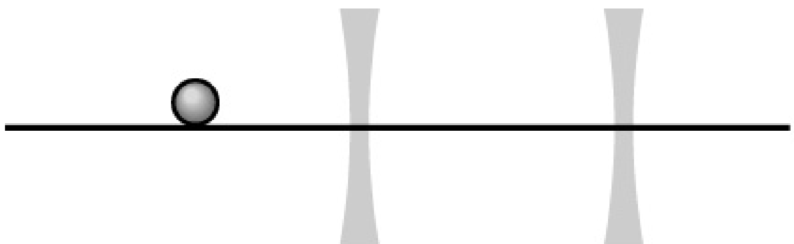


Problem 8
A bright object and a viewing screen are separated by a distance of 76.0 cm. At what location(s) between the object and the screen should a lens of focal length 16.0 cm be placed in order to produce a crisp image on the screen?

Problem 9
A movie camera with a (single) lens of focal length 75 mm takes a picture of a person standing 27 m away. If the person is 180 cm tall, what is the height of the image on the film?

Problem 10

In the figure below, a pea sits at a focal point of the first (nearer) thin diverging lens, 4.00 cm from that lens. The lenses are identical and separated by 10.0 cm, with a common central axis. (a) Where is the image of the pea produced by the second lens? (b) Is that image inverted or does it have the same orientation as the pea? (c) Is it real or virtual?



Problem 11

In the figure below, an object is placed in front of a converging lens at a distance equal to twice the focal length *f*1 of the lens. On the other side of the lens is a concave mirror of focal length *f*2 separated from the lens by a distance 2(*f*1 + *f*2). Light from the object passes rightward through the lens, reflects from the mirror, passes leftward through the lens, and forms a final image of the object. What are (a) the distance between the lens and that final image and (b) the overall lateral magnification *M* of the object? Is the image (c) real or virtual (if it is virtual, it requires someone looking through the lens toward the mirror), (d) to the left or right of the lens, and (e) inverted or non-inverted relative to the object?