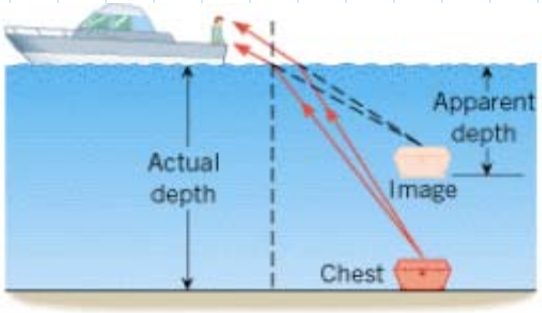
Chapter 34. Images

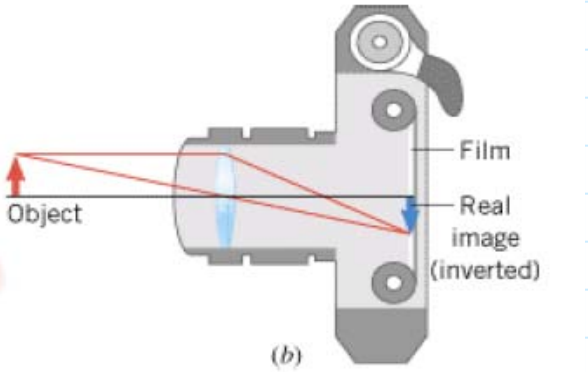
What is Physics?

Two Types of Image



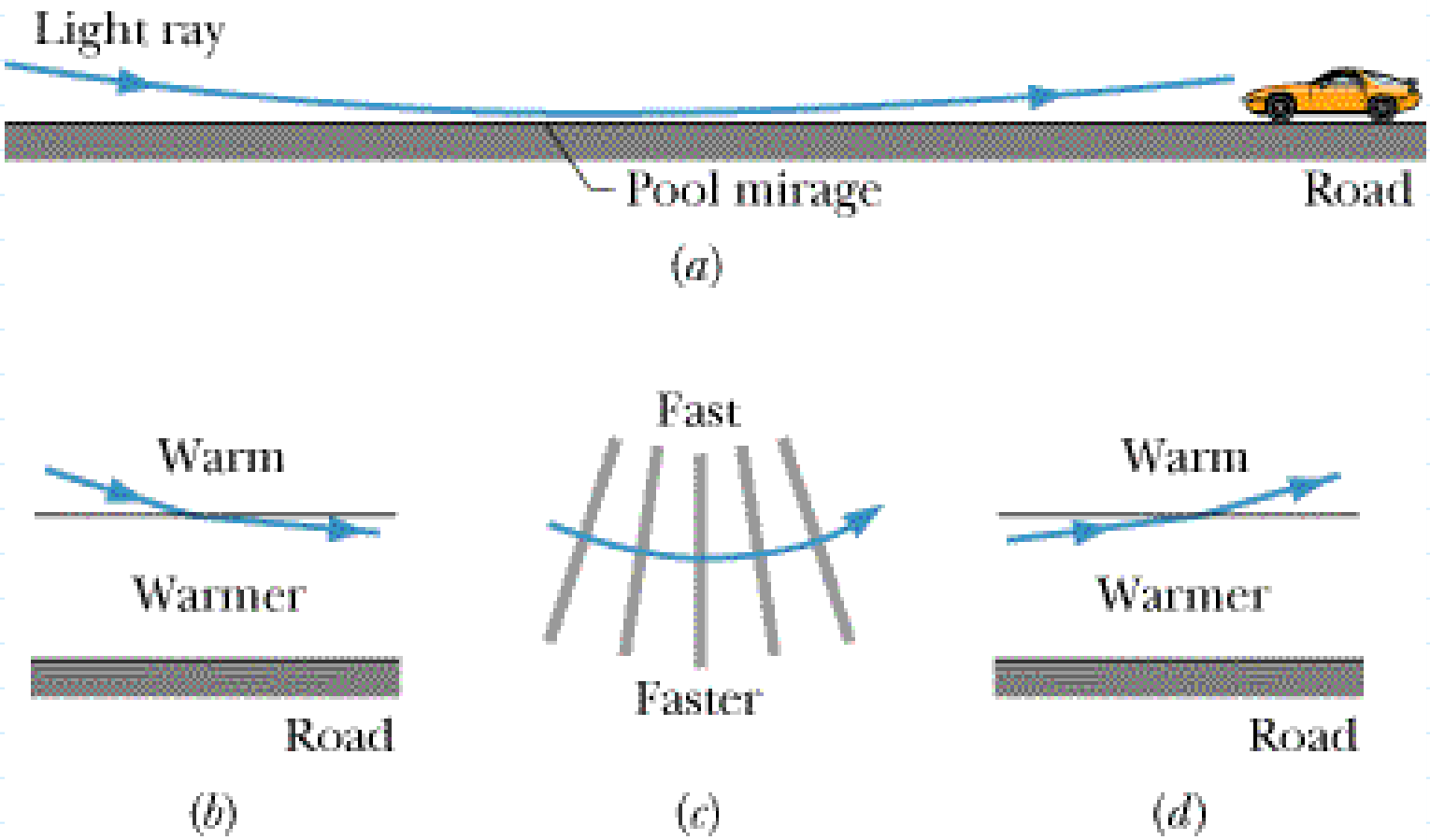
Formation an image:

The apparent location of an object is the common point from which the diverging straight line light rays seem to have come (even if the light rays have actually been bent).

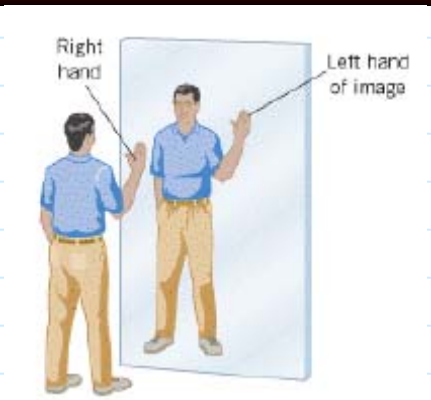


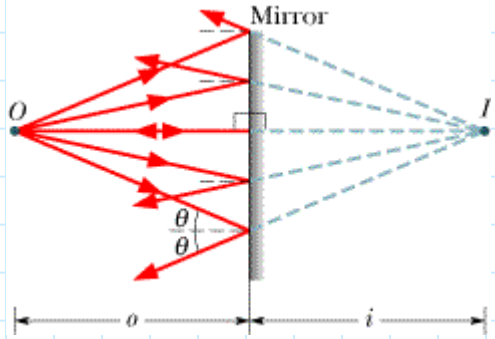
- ***The virtual images*** are the images that none of the light rays actually emanate from them.
- ***Real images*** are those from which all the light rays actually do emanate from them

A Common Mirage



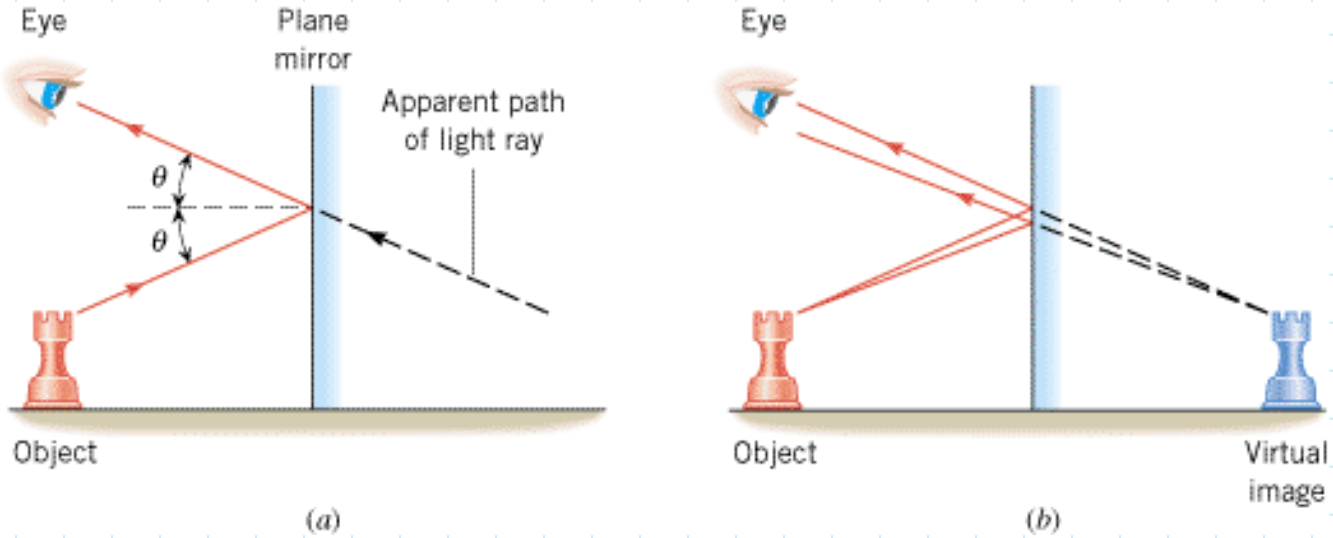
Plane Mirrors



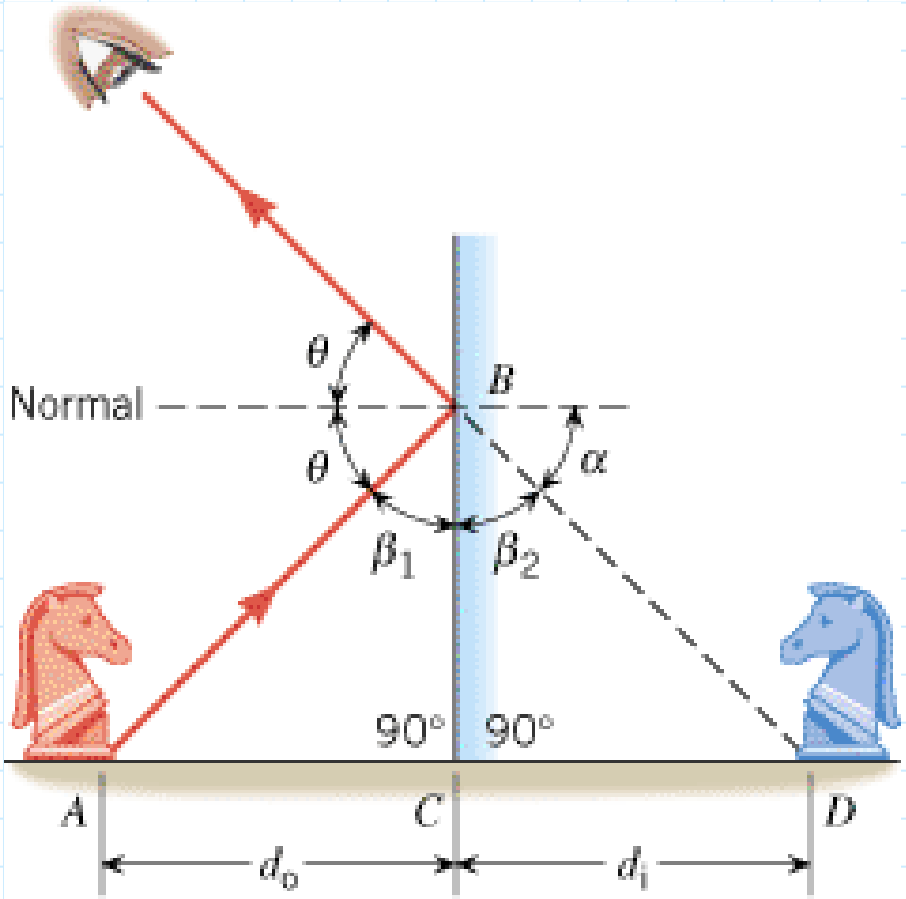


- The image is upright.
- The image is the same size as you are.
- The image is located as far behind the mirror as you are in front of it.

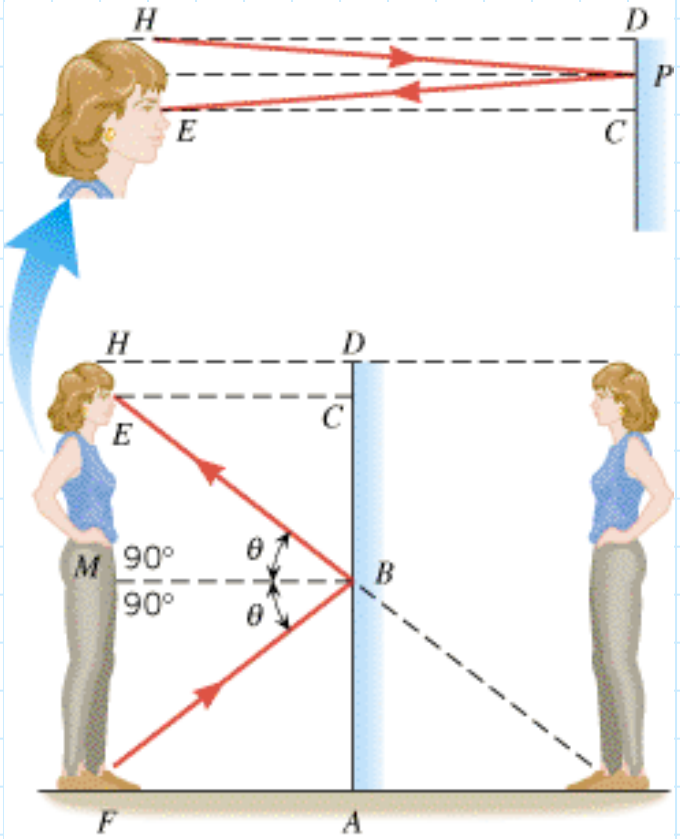
Why an image appears to originate from behind a plane mirror and upright?



Why the image is located as far behind a plane mirror as the object is in front of it?



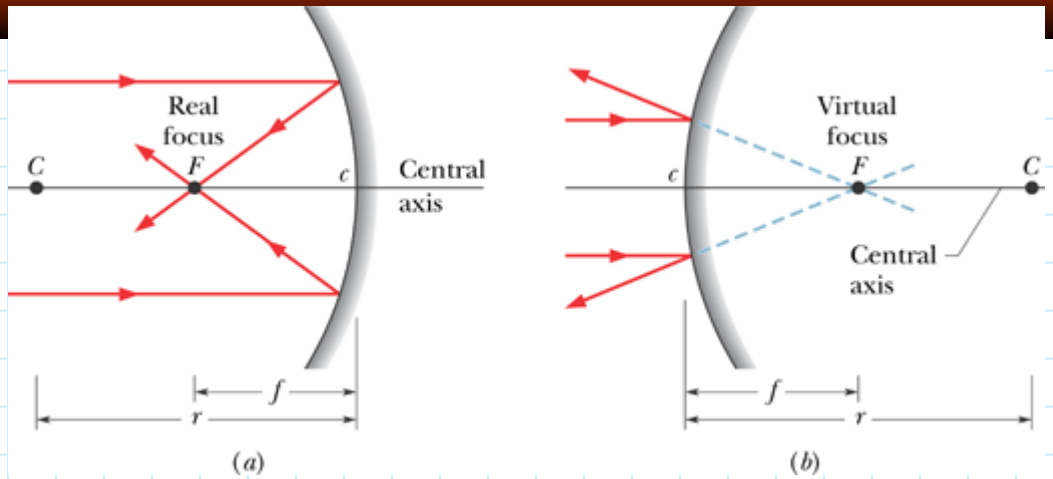
Conceptual Example. Full-Length Versus Half-Length Mirrors



In Figure a woman is standing in front of a plane mirror. What is the minimum mirror height necessary for her to see her full image?

Spherical Mirrors

concave mirror



convex mirror

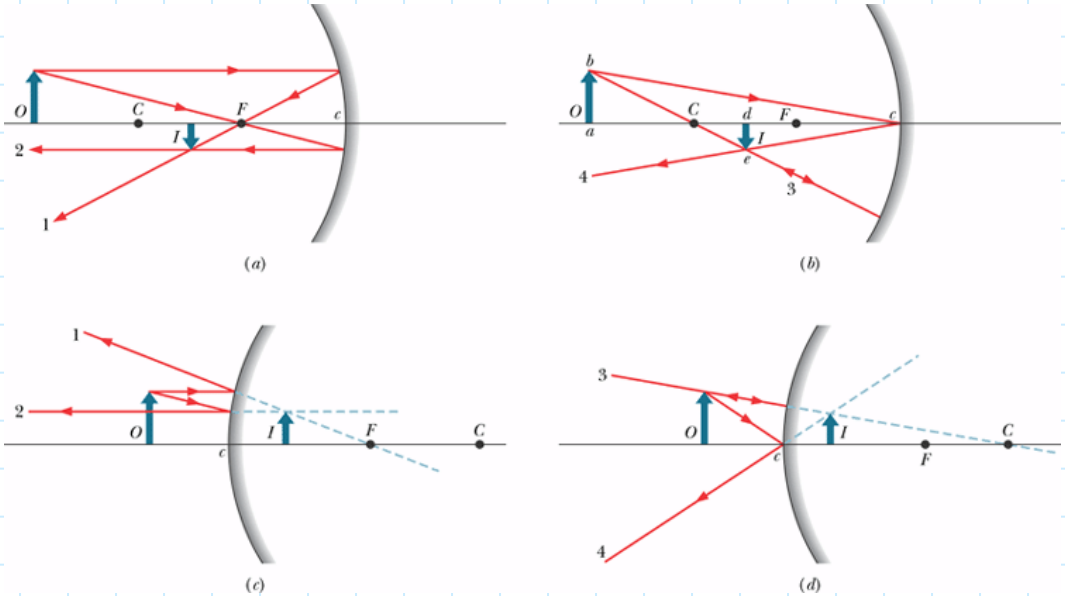
- For the radius of curvature *r* of the mirror, *r* is a positive quantity for a concave mirror and a negative quantity for a convex mirror.

- When the parallel rays reach a spherical mirror, those near the central axis are reflected through a common point *F*; Point *F* is called the **focal point** (or **focus**) of the mirror, and its distance from the center of the mirror *c* is the **focal length** of the mirror.

- The focal length *f* of a concave mirror is taken to be a positive quantity, and that of a convex mirror a negative quantity.

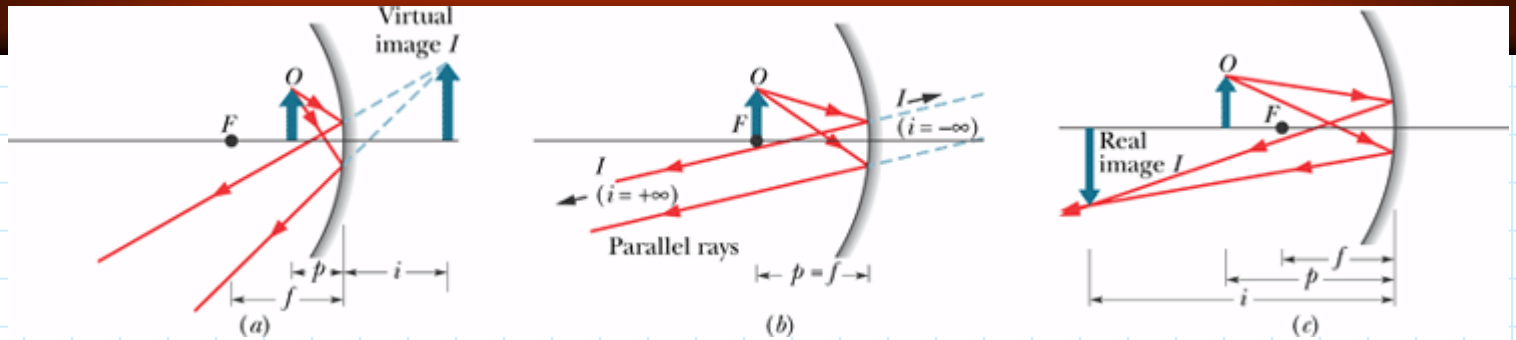
$$f = \frac{1}{2}r \text{ (spherical mirror)} .$$

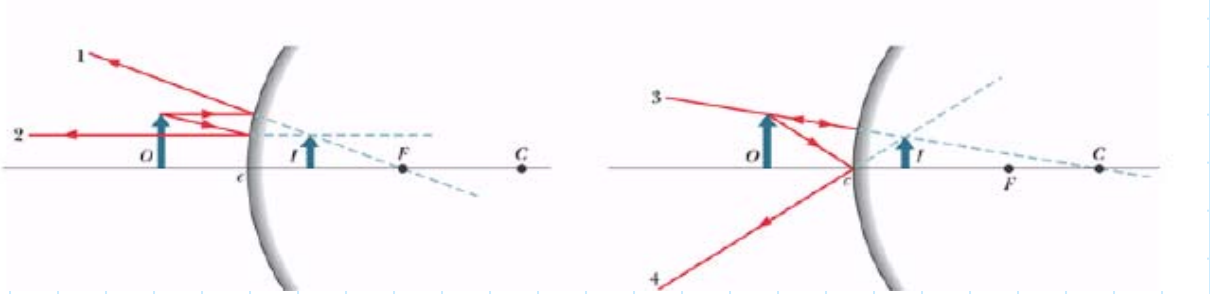
Locating Images by Drawing Rays



1. A ray that is initially parallel to the central axis reflects through the focal point *F* (ray 1 in Fig. *a*).
2. A ray that reflects from the mirror after passing through the focal point emerges parallel to the central axis ray 2 in Fig. *a*).
3. A ray that reflects from the mirror after passing through the center of curvature *C* returns along itself (ray 3 in Fig. *b*).
4. A ray that reflects from the mirror at point *c* is reflected symmetrically about that axis (ray 4 in Fig. *b*).

Images from Spherical Mirrors





- Real images form on the side of a mirror where the object is. The image distance *i* of a real image is a positive
- Virtual images form on the opposite side of object. The image distance *i* of a virtual image is negative.

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f}$$

Lateral Magnification

- Let *h* represent the height of the object, and *h'* the height of the image. If the object/image is upward, the height is positive; if the object/image is downward, the height is negative.

- The **lateral magnification** *m* produced by the mirror is:

$$m = \frac{h'}{h} \quad \text{or} \quad m = -\frac{i}{o}$$

- The **lateral magnification** *m* has a plus sign when the image and the object have the same orientation and a minus sign when the image orientation is opposite that of the object.

Summary

Mirror Type	Object Location	Image			Sign		
		Location	Type	Orientation	of *f*	of *r*	of *m*
Plane	Anywhere	opposite side	virtual	same	+	+	+1
Concave	Inside *F*	opposite	virtual	same	+	+	+
	Outside *F*	same side	real	opposite	+	+	-
Convex	Anywhere	opposite	virtual	same	-	-	+

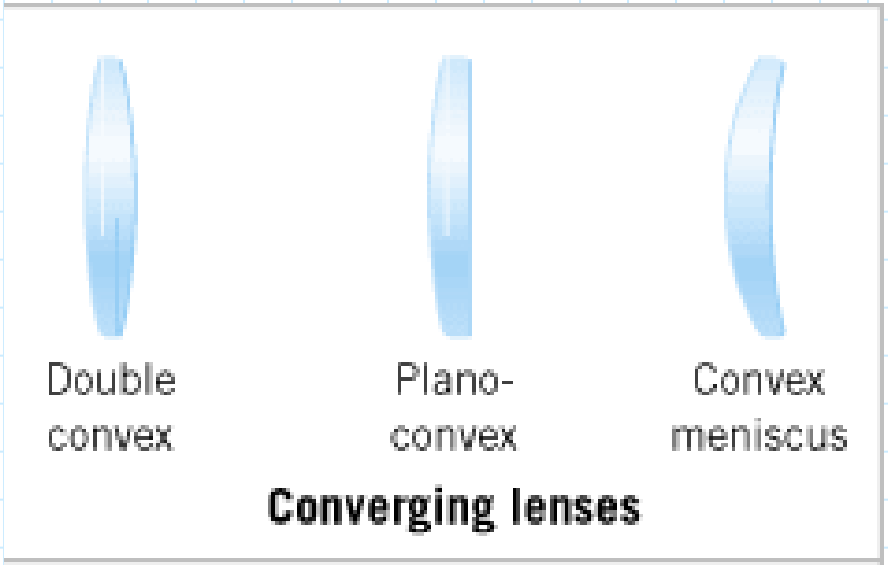
Sample Problem

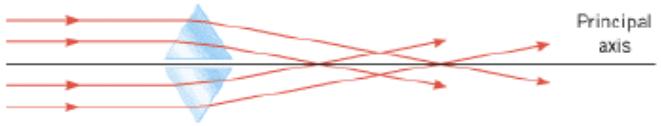
A tarantula of height h sits cautiously before a spherical mirror whose focal length has absolute value $|f| = 40$ cm. The image of the tarantula produced by the mirror has the **same orientation** as the tarantula and has height $h' = 0.20h$.

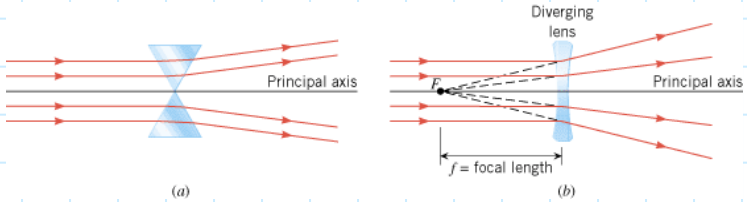
(a) Is the image real or virtual, and is it on the same side of the mirror as the tarantula or the opposite side?

(b) Is the mirror concave or convex, and what is its focal length f, sign included?

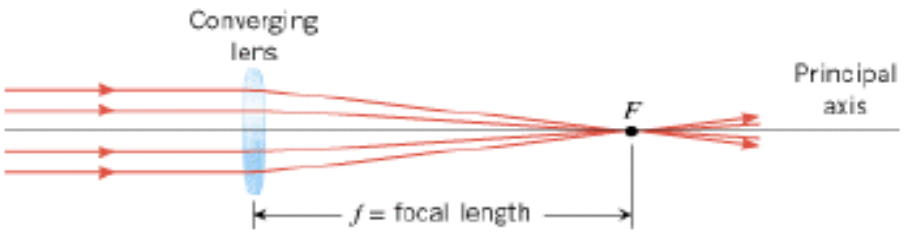
Lenses

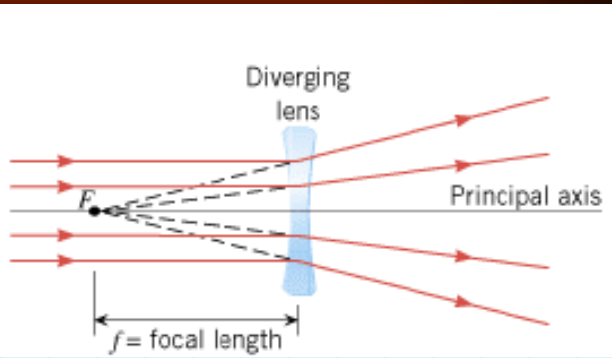

Double convex
Plano-convex
Convex meniscus
Converging lenses
Double concave
Plano-concave
Concave meniscus
Diverging lenses


Principal axis


Principal axis
(a)
Diverging lens
F
Principal axis
f = focal length
(b)

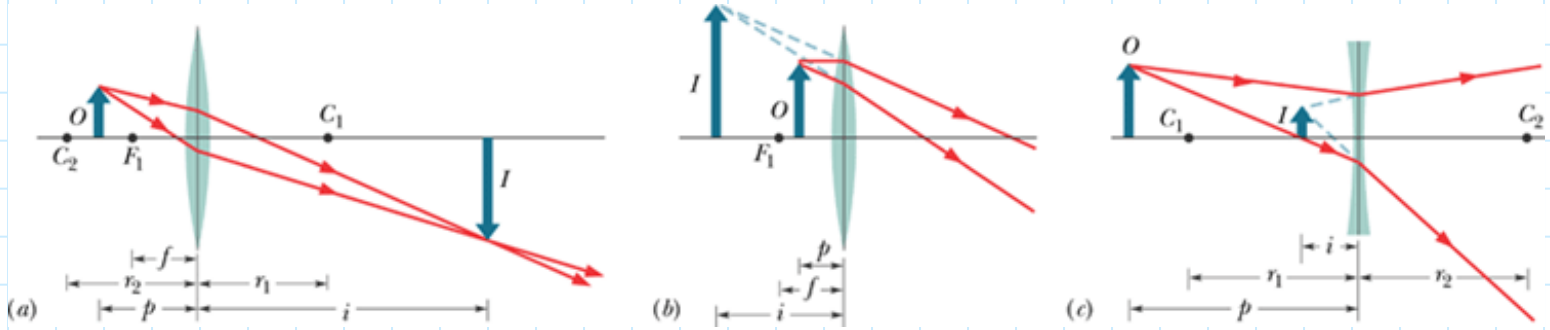
Thin Lens





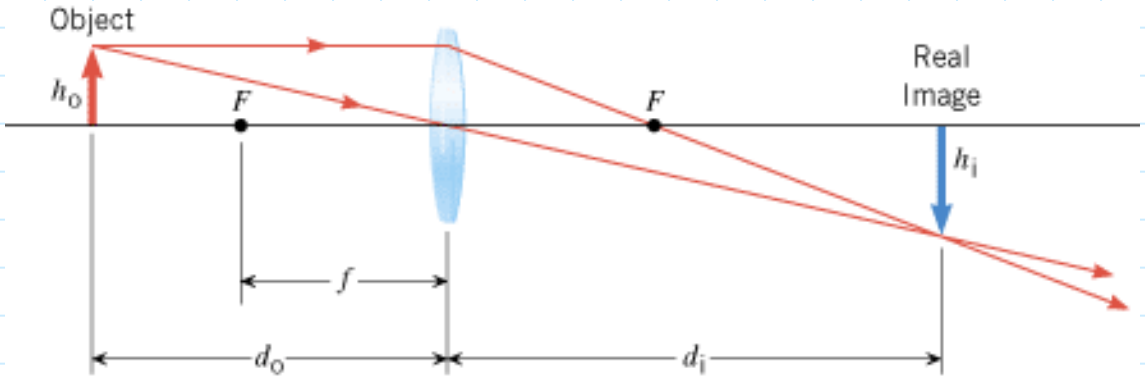
- **The thin lens**—that is, a lens in which the thickest part is thin relative to the object distance o, the image distance *i*, and the radii of curvature *r*1 and *r*2 of the two surfaces of the lens.
- The rays that are near the principal axis (paraxial rays) and parallel to it converge to a single point on the axis after emerging from the lens. This point is called the ***focal point F*** of the lens.
- The distance between the focal point and the lens is the ***focal length f. The f is positive for a converging lens and is negative for a diverging lens.***
- For a thin lens, these two focal points are equidistant from the lens.

Images from Thin Lenses



- A lens can produce an image of an object only because the lens can bend light rays, but it can bend light rays only if its index of refraction differs from that of the surrounding medium.
- Real images form on the side of a lens that is opposite the object, and virtual images form on the side where the object is.

Thin-Lens Equation and the Magnification Equation



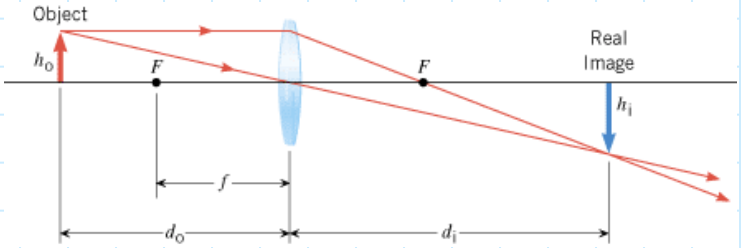
Thin-lens equation:

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

Magnification Equation:

$$m=\frac{\text{Image height}}{\text{Object height}}=\frac{h_i}{h_o}=-\frac{d_i}{d_o}$$

Summary of Sign Conventions for Lenses



(1) Focal length

f is + for a converging lens. *f* is – for a diverging lens.

(2) Object distance

o is + if the object is to the left of the lens (real object), as is usual. o is – if the object is to the right of the lens (virtual object)

(3) ***Image distance***

i is + for an image (real) formed to the right of the lens by a real object. i is – for an image (virtual) formed to the left of the lens by a real object.

(4) Magnification

m is + for an image that is upright with respect to the object. *m* is – for an image that is inverted with respect to the object.

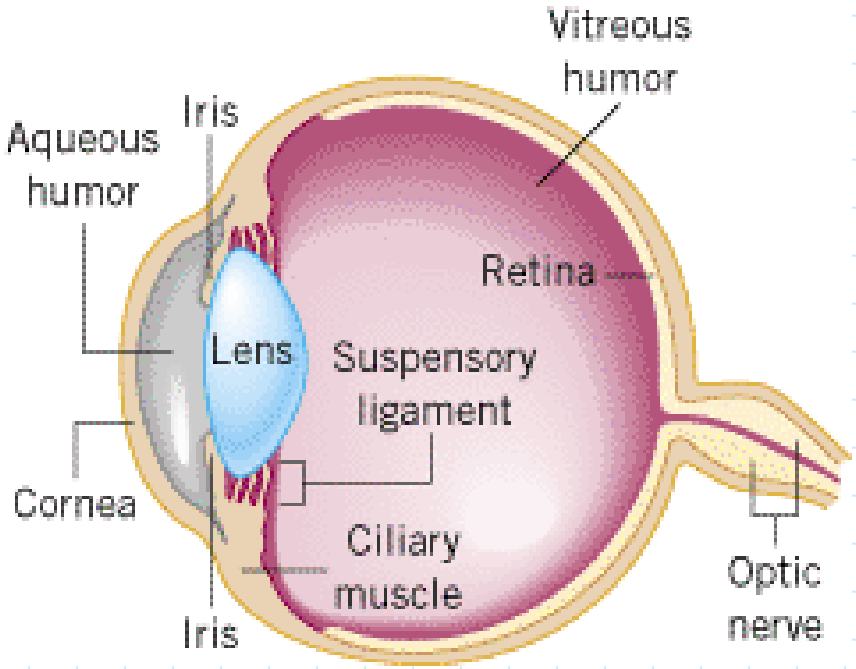
Example. The Real Image Formed by a Camera Lens

A 1.70-m-tall person is standing 2.50 m in front of a camera. The camera uses a converging lens whose focal length is 0.0500 m. (a) Find the image distance (the distance between the lens and the film) and determine whether the image is real or virtual. (b) Find the magnification and the height of the image on the film.

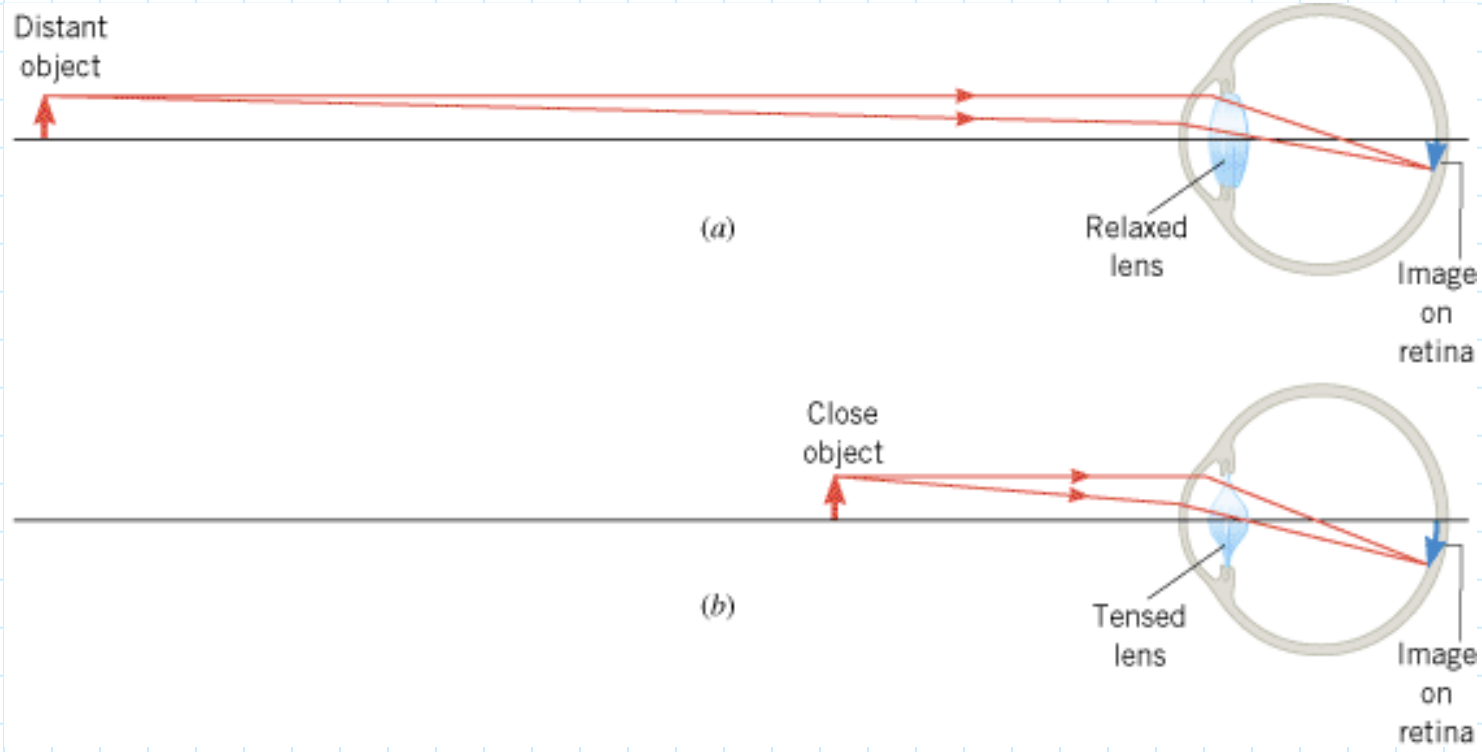
Example. The Virtual Image Formed by a Diverging Lens

An object is placed 7.10 cm to the left of a diverging lens whose focal length is f=-5.08 cm (a diverging lens has a negative focal length). (a) Find the image distance and determine whether the image is real or virtual. (b) Obtain the magnification.

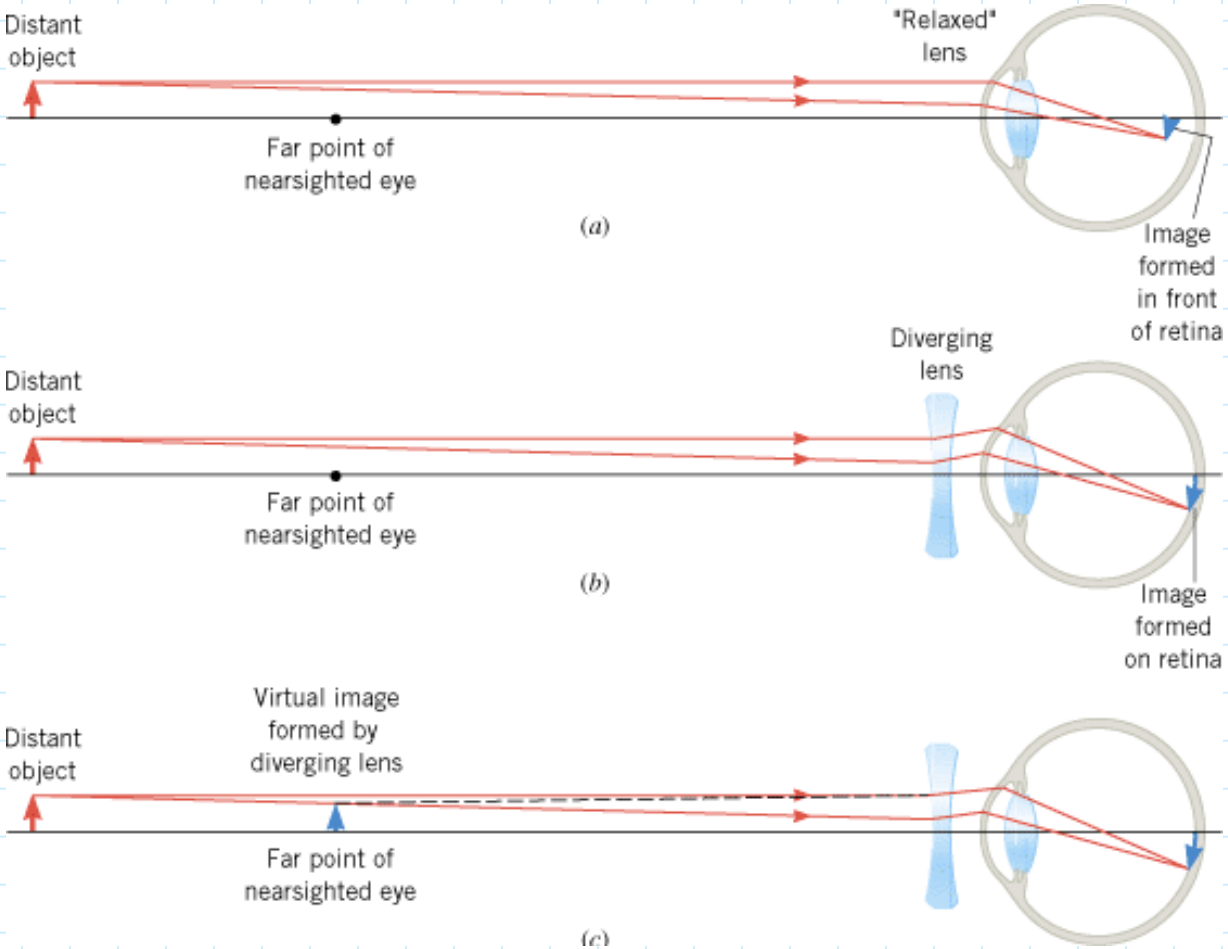
Human Eye


Vitreous humor
Iris
Aqueous humor
Retina
Lens
Suspensory ligament
Cornea
Ciliary muscle
Optic nerve
Iris

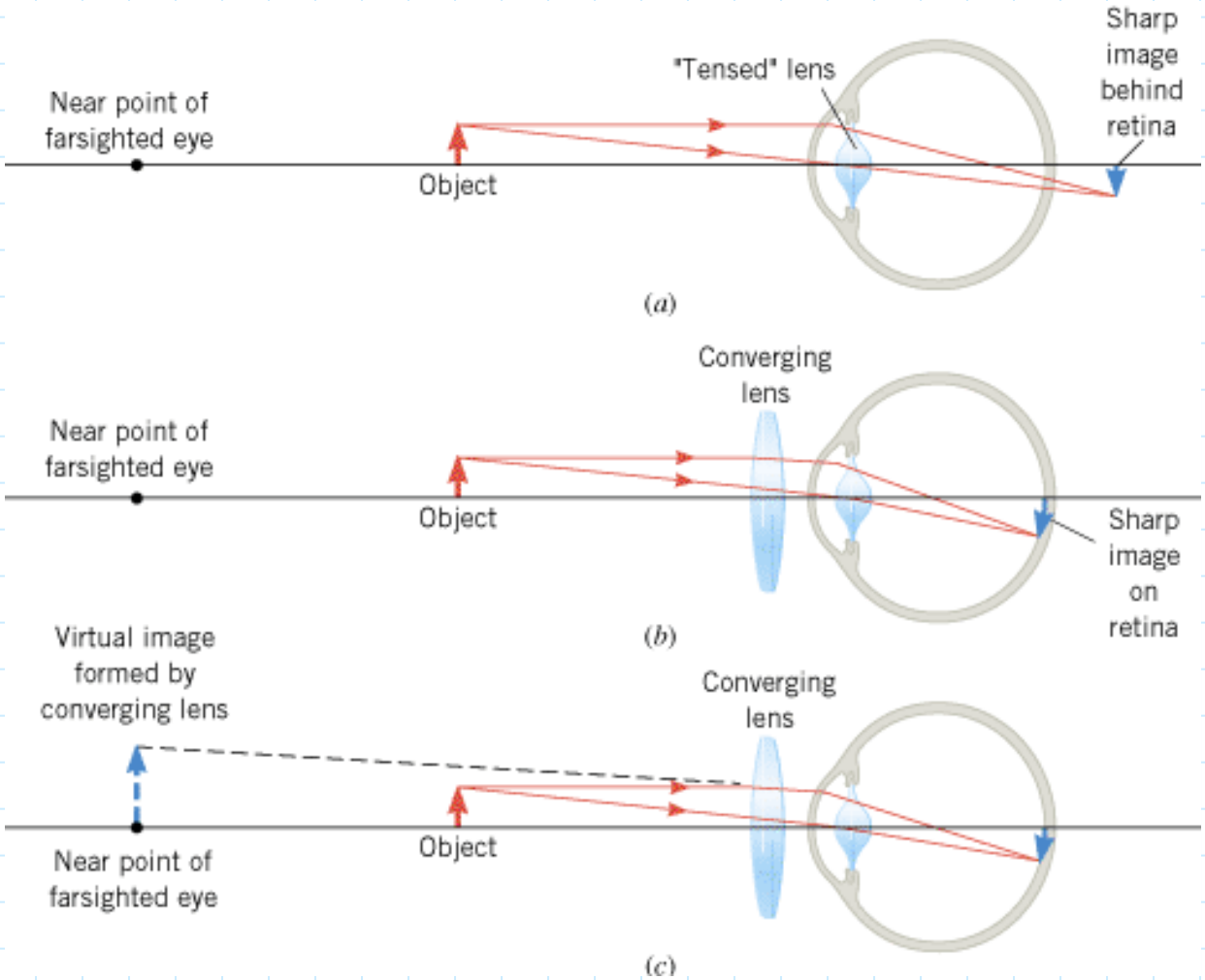
Accommodation



NEARSIGHTEDNESS



FARSIGHTEDNESS



THE REFRACTIVE POWER OF A LENS — THE DIOPTER

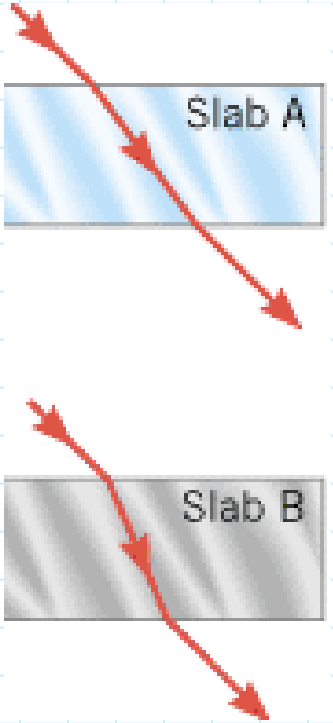
Refractive power of lens:

$$P = \frac{1}{f \text{ (in meters)}}$$

The refractive power is measured in units of *diopters.* (1 diopter = 1 m^{-1})

Conceptual Questions

1. Two slabs with parallel faces are made from different types of glass. A ray of light travels through air and enters each slab at the same angle of incidence, as the drawing shows. Which slab has the greater index of refraction? Why?



Conceptual Questions

2. A man is fishing from a dock. (a) If he is using a bow and arrow, should he aim above the fish, at the fish, or below the fish, to strike it? (b) How would he aim if he were using a laser gun? Give your reasoning.
3. A person sitting at the beach is wearing a pair of Polaroid sunglasses and notices little discomfort due to the glare from the water on a bright sunny day. When she lies on her side, however, she notices that the glare increases. Why?
4. If we read for a long time, our eyes become "tired." When this happens, it helps to stop reading and look at a distant object. From the point of view of the ciliary muscle, why does this refresh the eyes?