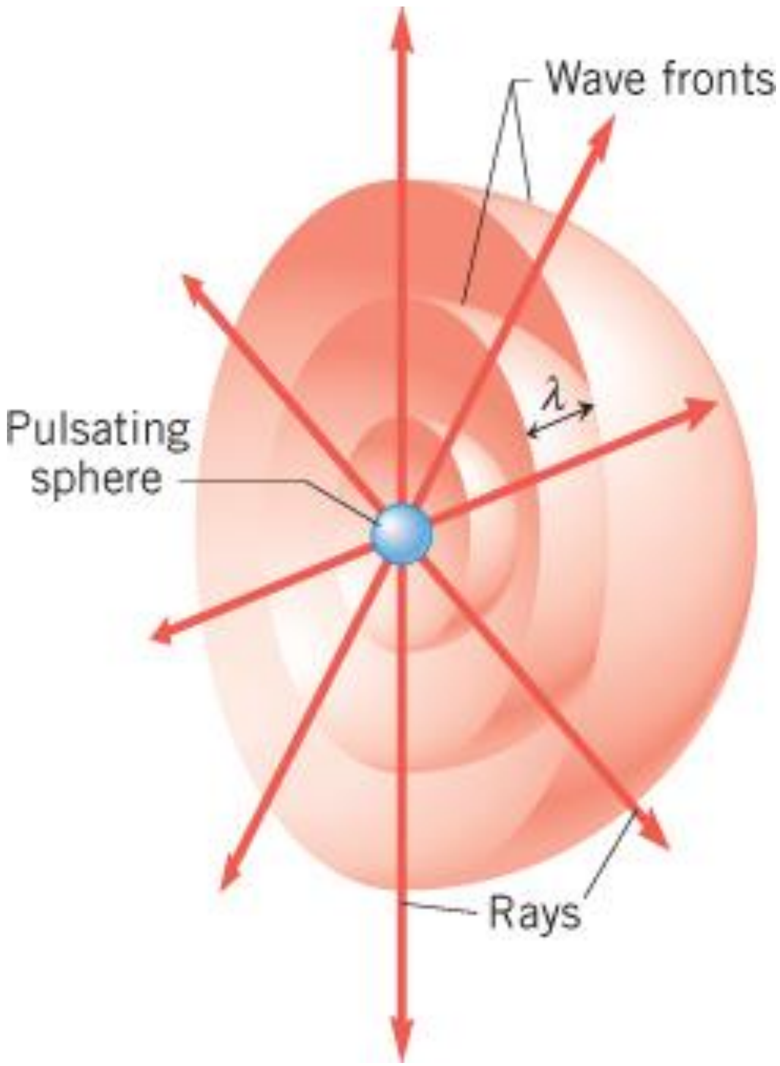
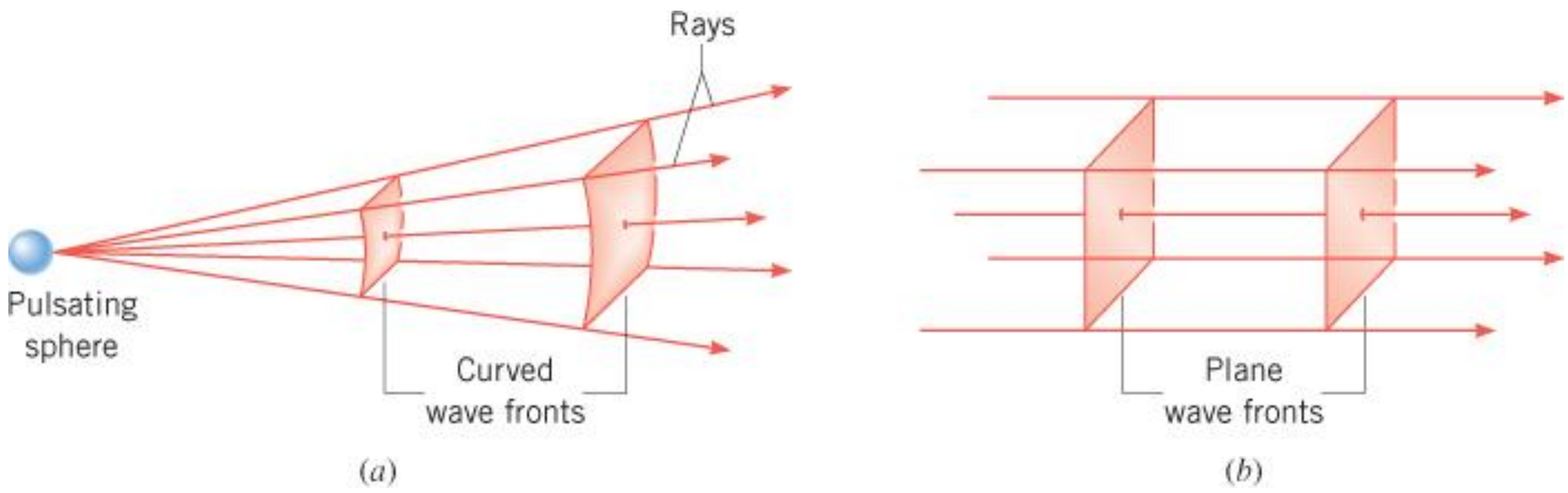
Chapter 25

The Reflection of Light: Mirrors



A hemispherical view of
a sound wave emitted by a
pulsating sphere.

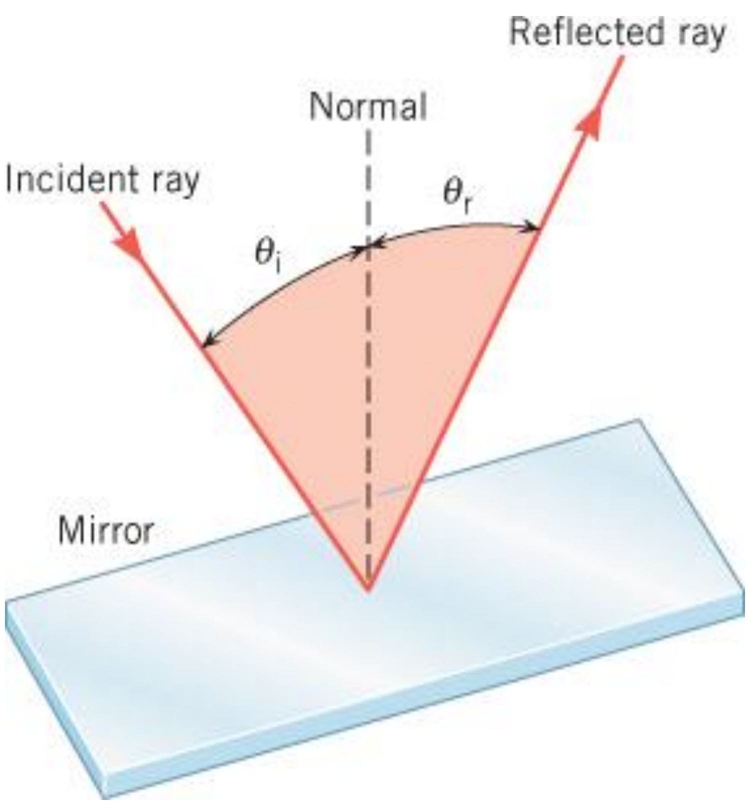
The rays are perpendicular
to the wave fronts.

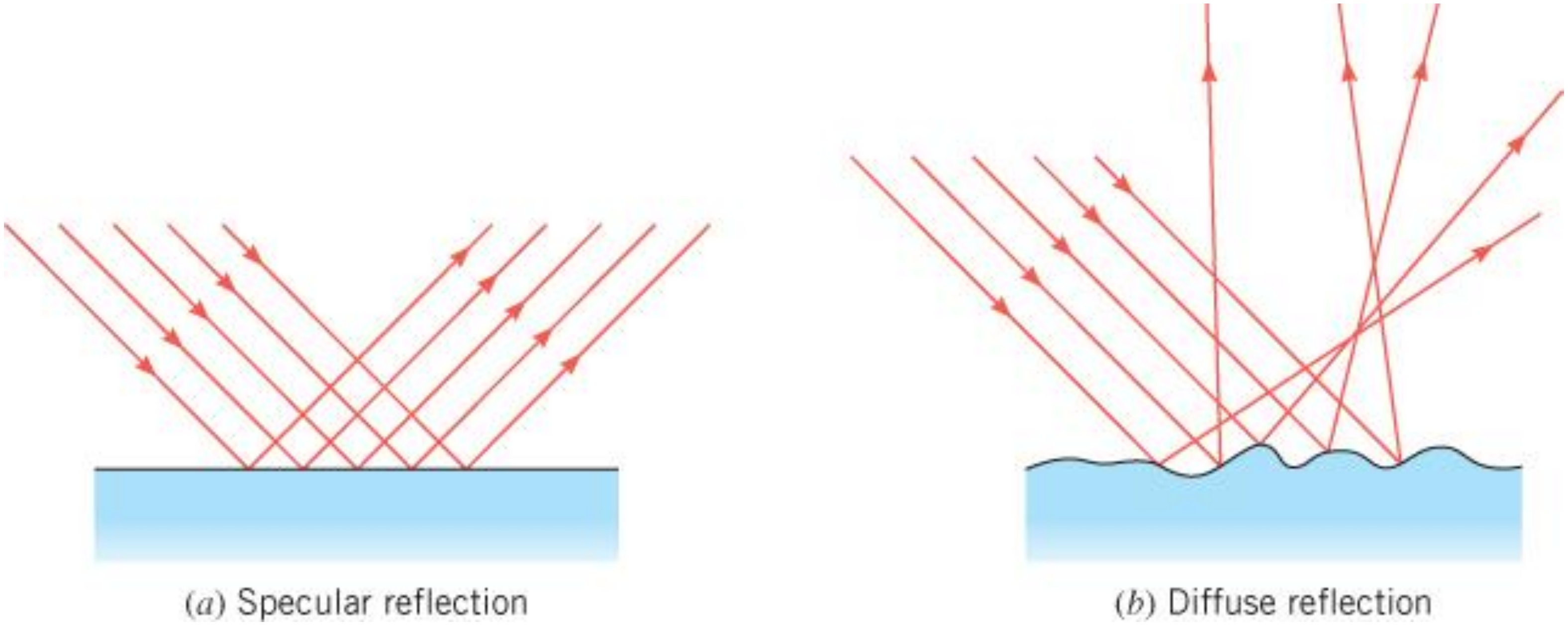


At large distances from the source, the wave fronts become less and less curved.

LAW OF REFLECTION

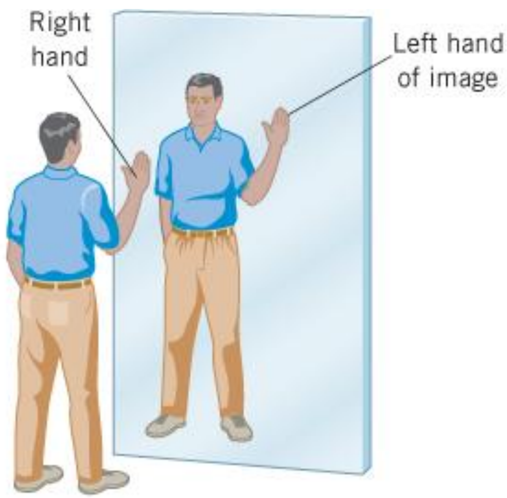
The incident ray, the reflected ray, and the normal to the surface all lie in the same plane, and the angle of incidence equals the angle of reflection.





In specular reflection, the reflected rays are parallel to each other.

25.3 The Formation of Images by a Plane Mirror



(a)

(b)

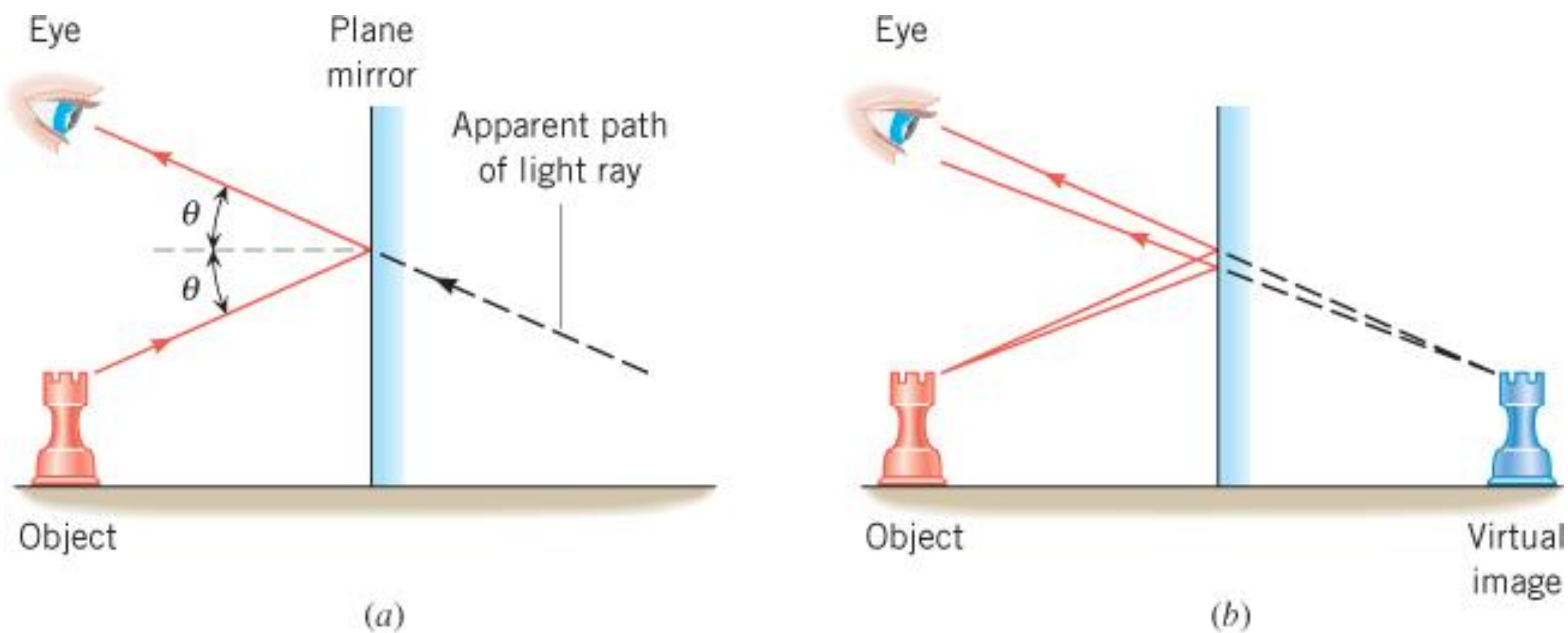
The person's right hand becomes the image's left hand.

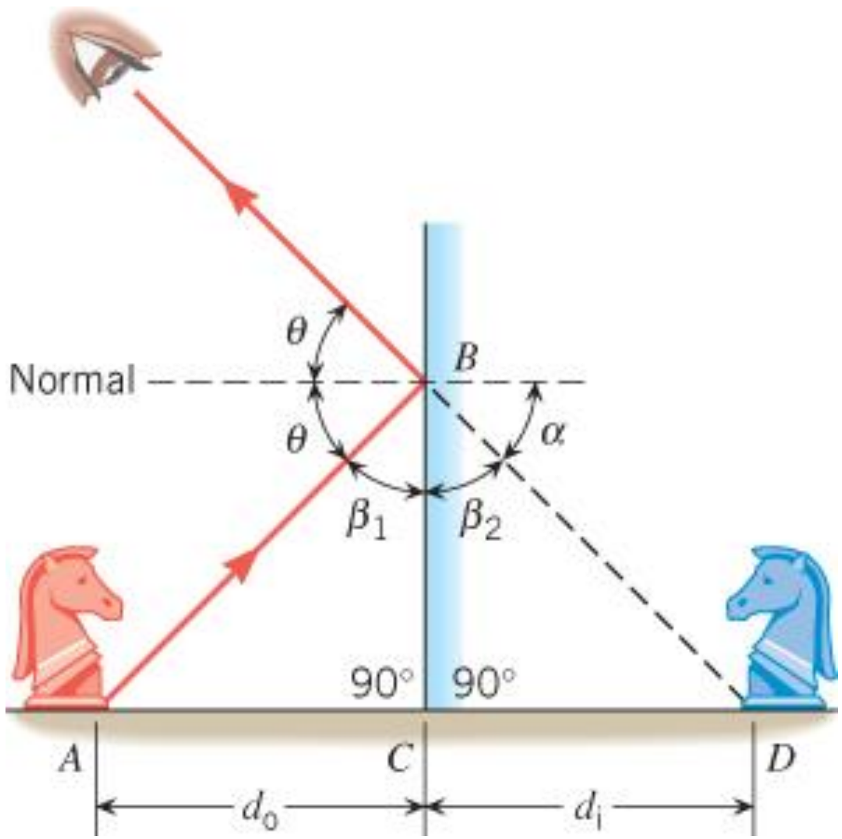
The image has three properties:

1. It is upright.
2. It is the same size as you are.
3. The image is as far behind the mirror are you are in front of it.

A ray of light from the top of the chess piece reflects from the mirror. To the eye, the ray seems to come from behind the mirror.

Because none of the rays actually emanate from the image, it is called a ***virtual image.***

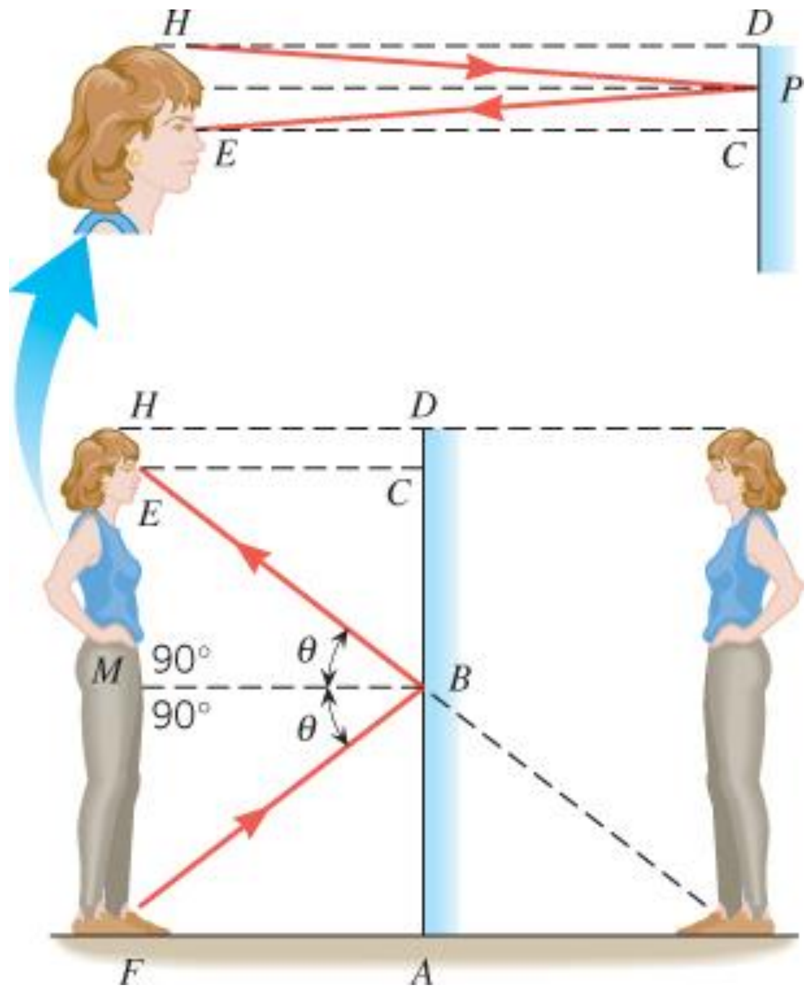




The geometry used to show that the image distance is equal to the object distance.

Conceptual Example 1 Full-Length Versus Half-Length Mirrors

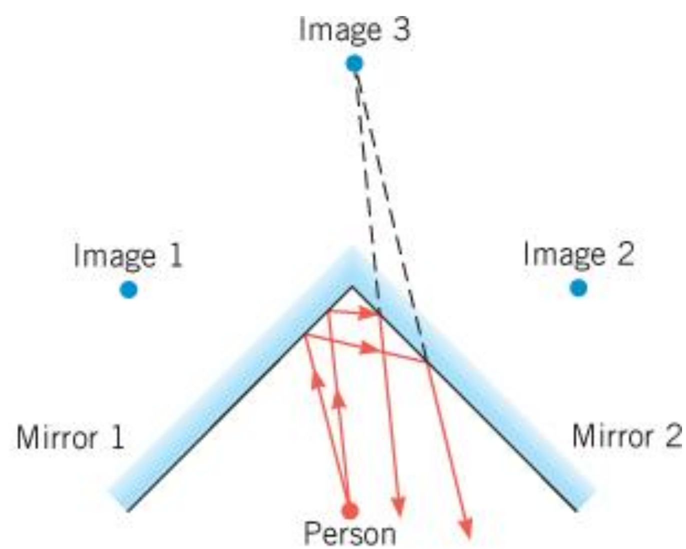
What is the minimum mirror height necessary for her to see her full image?



Conceptual Example 2 Multiple Reflections

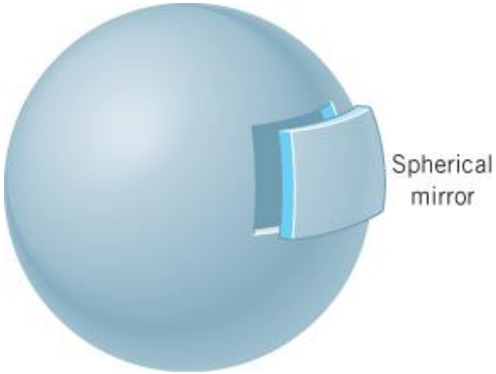
A person is sitting in front of two mirrors that intersect at a right angle. The person sees three images of herself. Why are there three, rather than two, images?

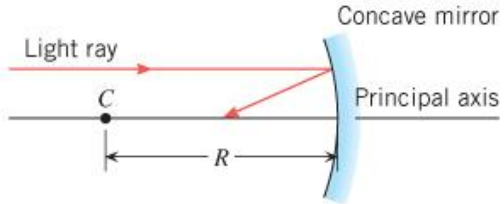
(a)

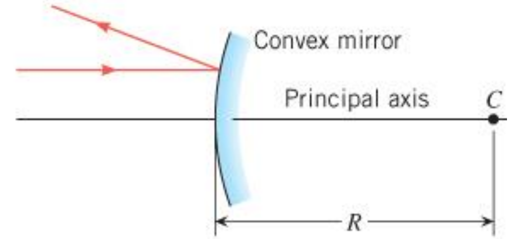


(b)

25.4 Spherical Mirrors



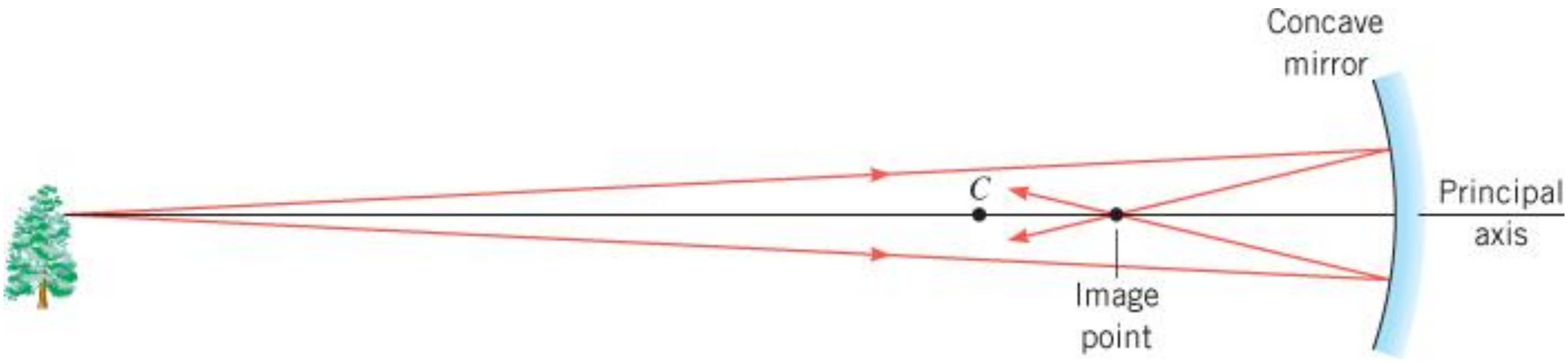




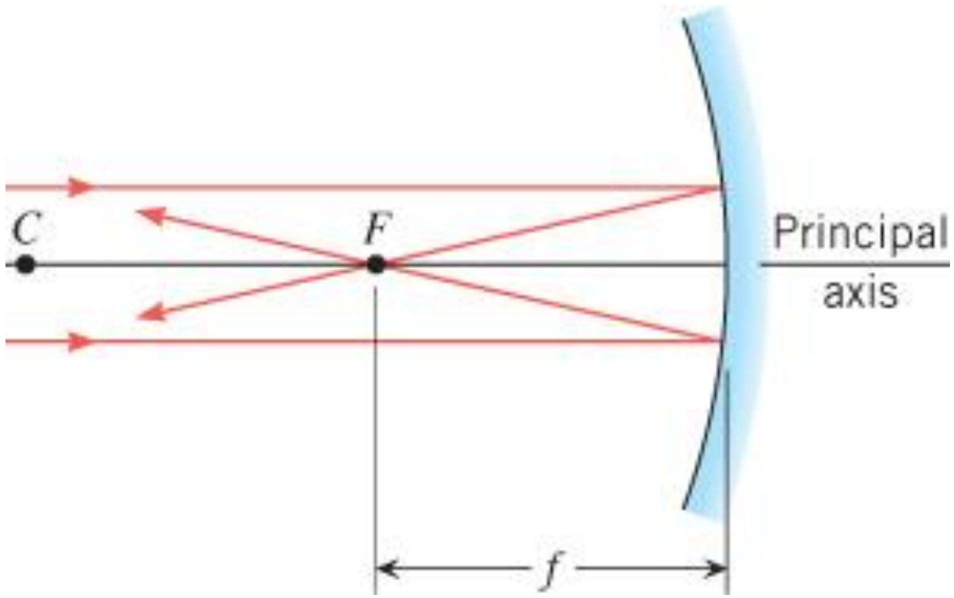
If the inside surface of the spherical mirror is polished, it is a ***concave mirror.*** If the outside surface is polished, is it a ***convex mirror.***

The law of reflection applies, just as it does for a plane mirror.

The ***principal axis*** of the mirror is a straight line drawn through the center of curvature and the midpoint of the mirror.

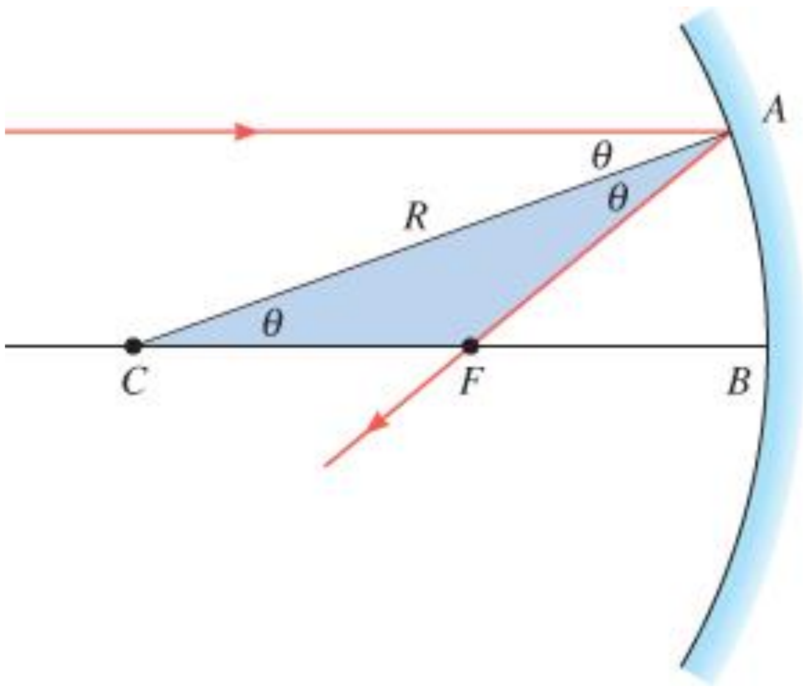


A point on the tree lies on the principal axis of the concave mirror. Rays from that point that are near the principal axis cross the axis at the image point.



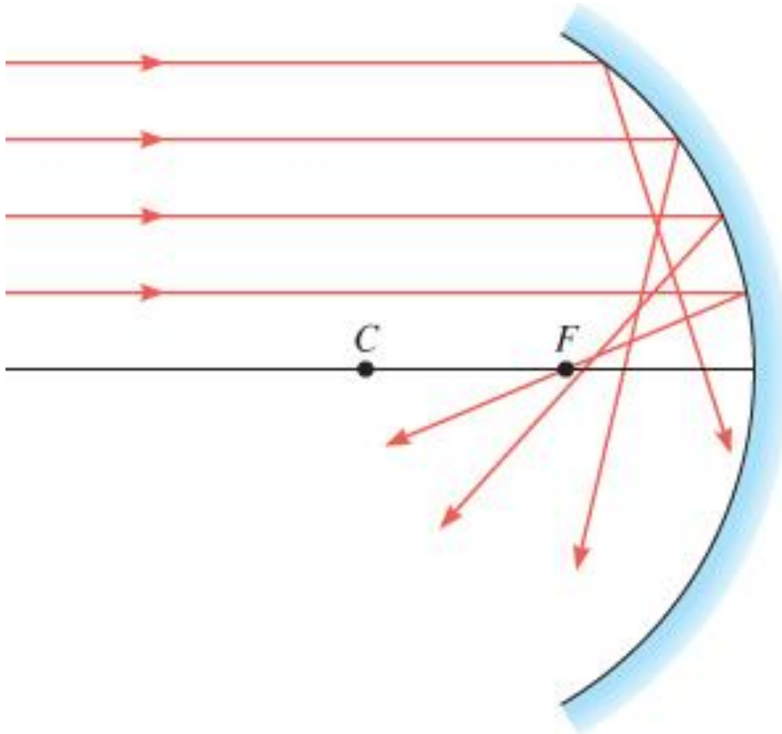
Light rays near and parallel to the principal axis are reflected from the concave mirror and converge at the focal point.

The focal length is the distance between the focal point and the mirror.



The focal point of a concave mirror is halfway between the center of curvature of the mirror C and the mirror at B.

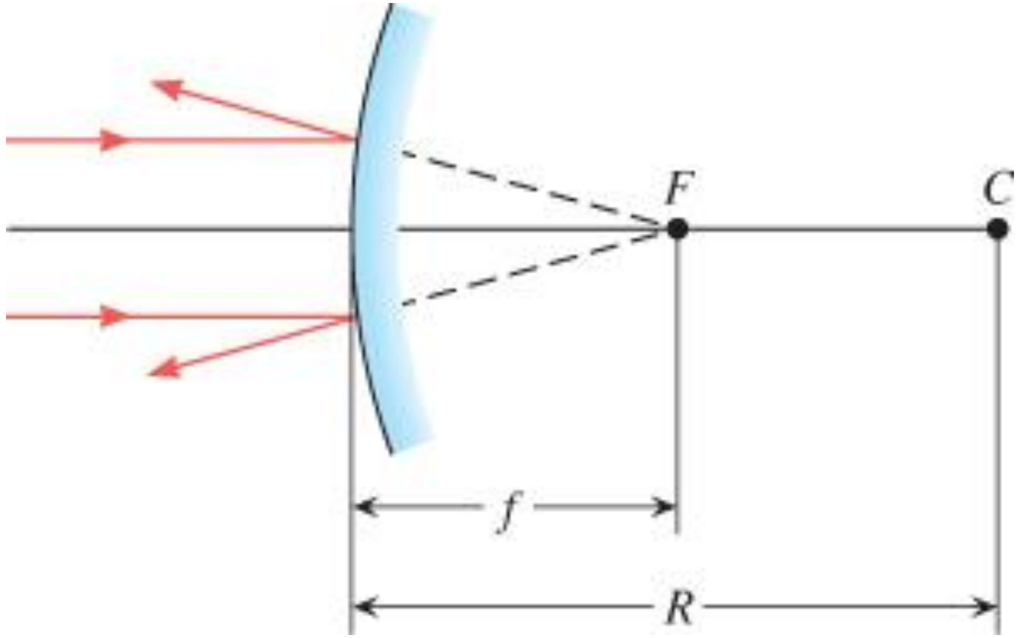
$$f = \tfrac{1}{2} R$$



Rays that lie close to the principal axis are called paraxial rays.

Rays that are far from the principal axis do not converge to a single point. The fact that a spherical mirror does not bring all parallel rays to a single point is known as ***spherical aberration.***

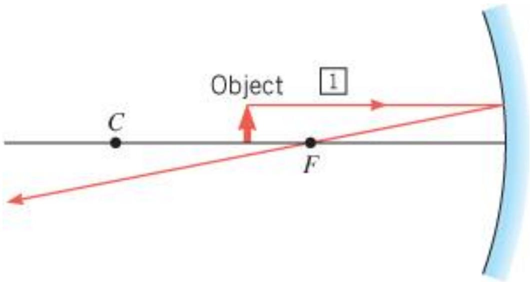
25.4 Spherical Mirrors



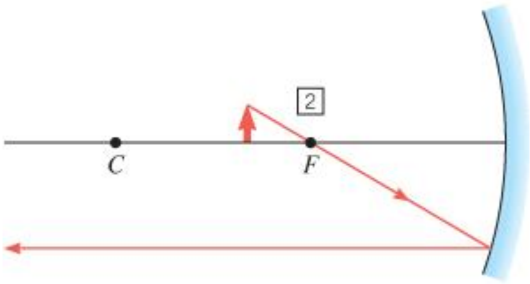
When paraxial light rays that are parallel to the principal axis strike a convex mirror, the rays appear to originate from the focal point.

$$f = -\tfrac{1}{2}R$$

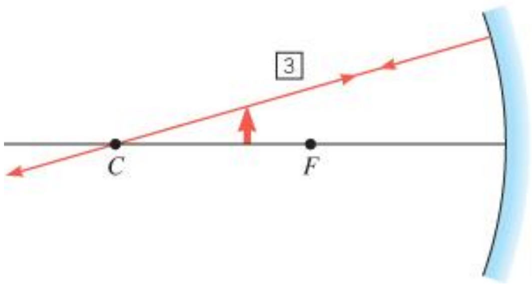
CONCAVE MIRRORS



This ray is initially parallel to the principal axis and passes through the focal point.

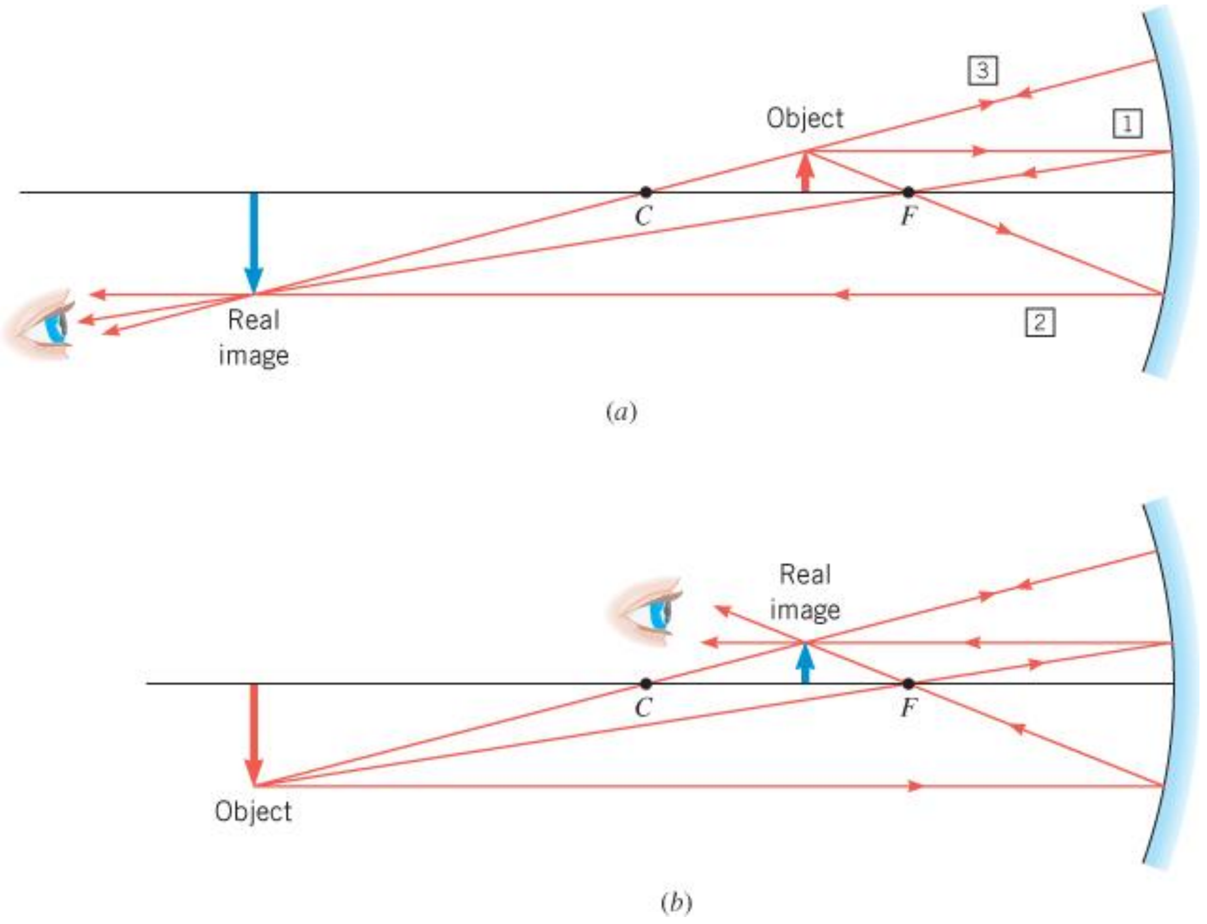


This ray initially passes through the focal point, then emerges parallel to the principal axis.

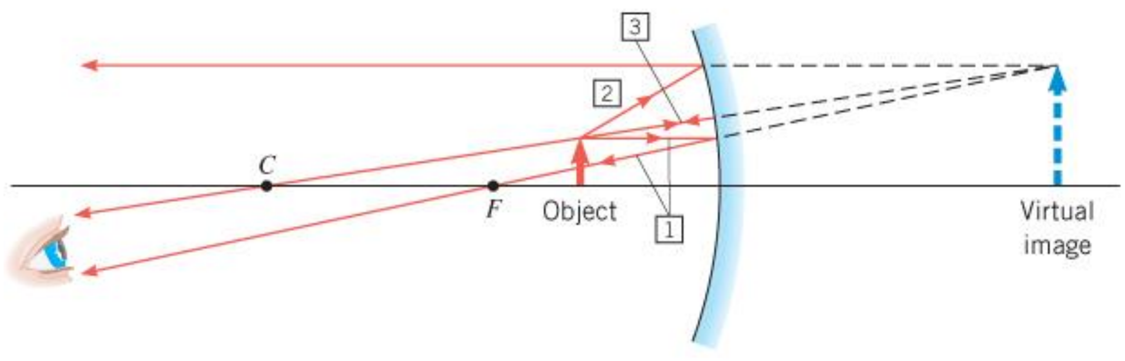


This ray travels along a line that passes through the center.

Image formation and the principle of reversibility



25.5 The Formation of Images by Spherical Mirrors



(a)

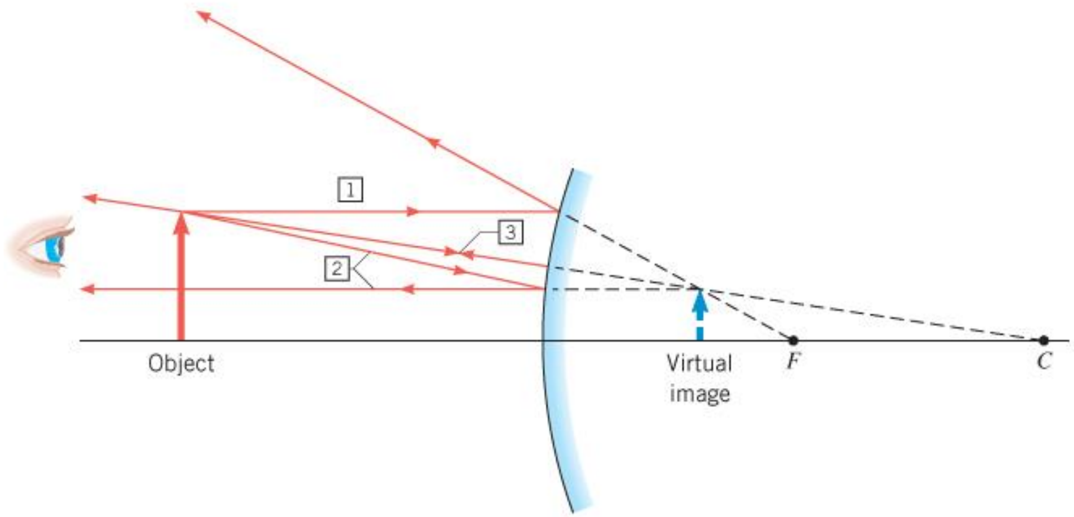
(b)

When an object is located between the focal point and a concave mirror, and enlarged, upright, and virtual image is produced.

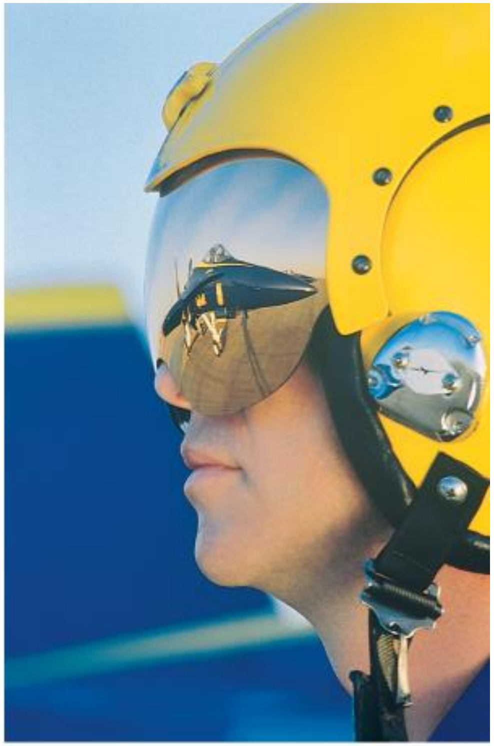
25.5 The Formation of Images by Spherical Mirrors

(a) (b)

CONVEX MIRRORS



(a)



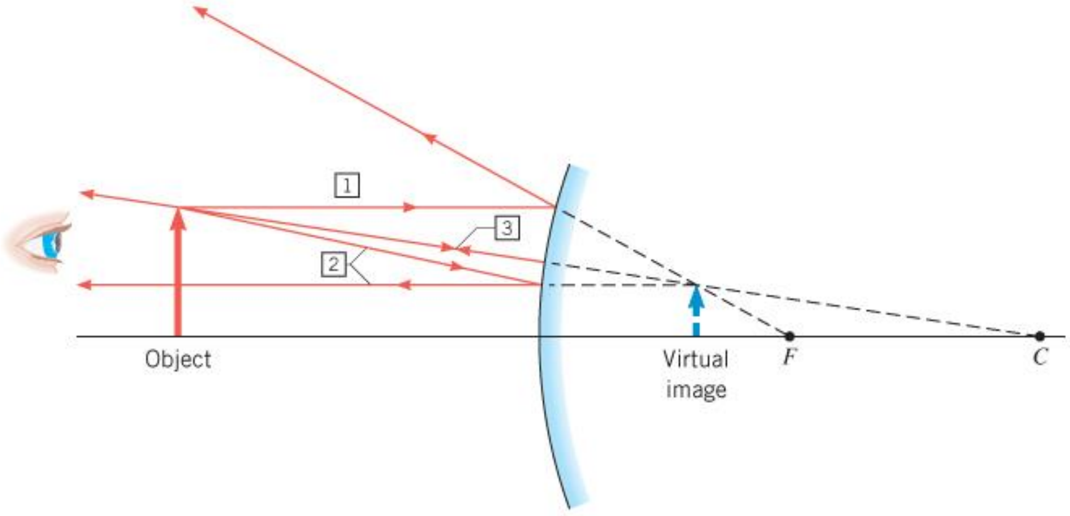
(b)

Ray 1 is initially parallel to the principal axis and appears to originate from the focal point.

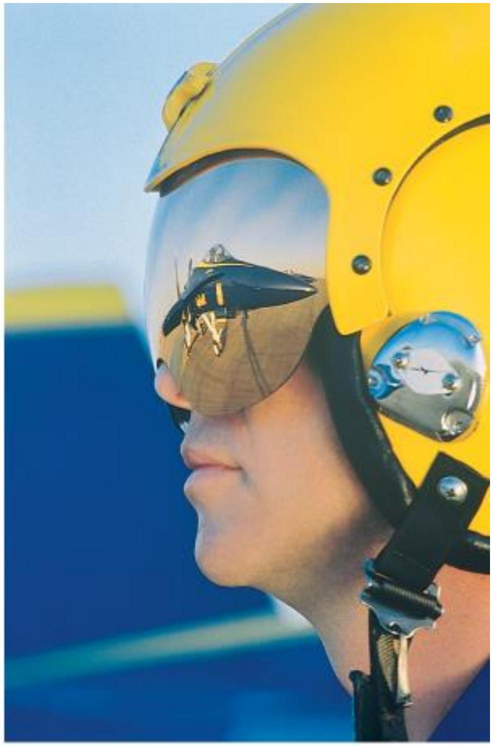
Ray 2 heads towards the focal point, emerging parallel to the principal axis.

Ray 3 travels toward the center of curvature and reflects back on itself.

25.5 The Formation of Images by Spherical Mirrors



(a)



(b)

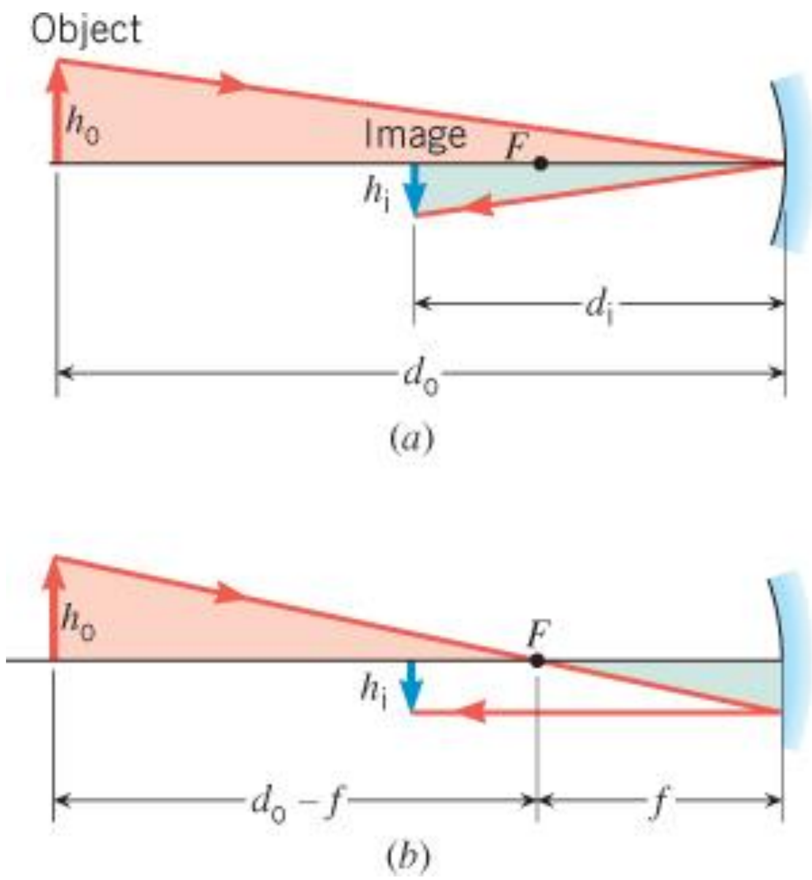
The virtual image is diminished in size and upright.

$$f = \text{focal length}$$

$$d_o = \text{object distance}$$

$$d_i = \text{image distance}$$

$$m = \text{magnification}$$



These diagrams are used to derive the mirror equation.

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

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

Example 5 **A Virtual Image Formed by a Convex Mirror**

A convex mirror is used to reflect light from an object placed 66 cm in front of the mirror. The focal length of the mirror is -46 cm. Find the location of the image and the magnification.

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_i} = \frac{1}{-46\text{ cm}} - \frac{1}{66\text{ cm}} = -0.037\text{ cm}^{-1}$$

$$d_i = -27\text{ cm}$$

$$m = -\frac{d_i}{d_o} = -\frac{(-27\text{ cm})}{66\text{ cm}} = 0.41$$

Summary of Sign Conventions for Spherical Mirrors

f is + for a concave mirror.

f is – for a convex mirror.

d_o is + if the object is in front of the mirror.

d_o is – if the object is behind the mirror.

d_i is + if the object is in front of the mirror (real image).

d_i is – if the object is behind the mirror (virtual image).

m is + for an upright object.

m is – for an inverted object.