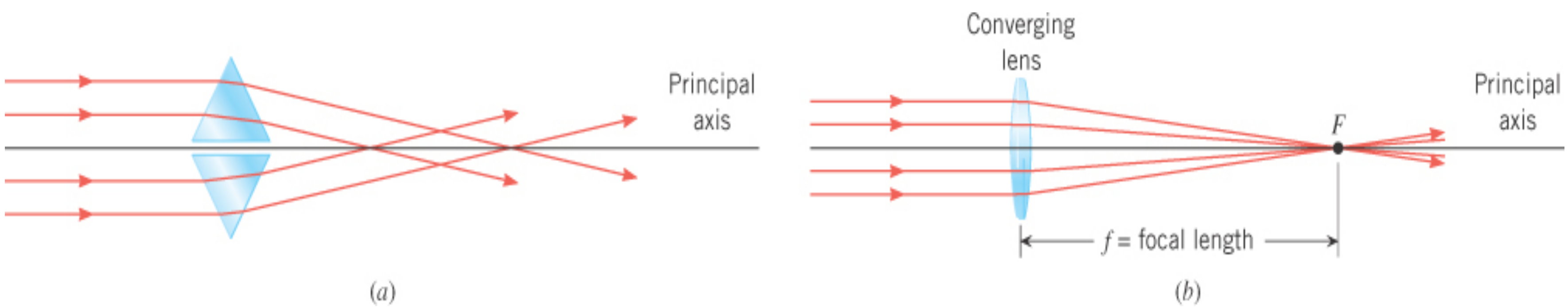
Lenses

Converging and diverging lenses.

Lenses refract light in such a way that an image of the light source is formed.

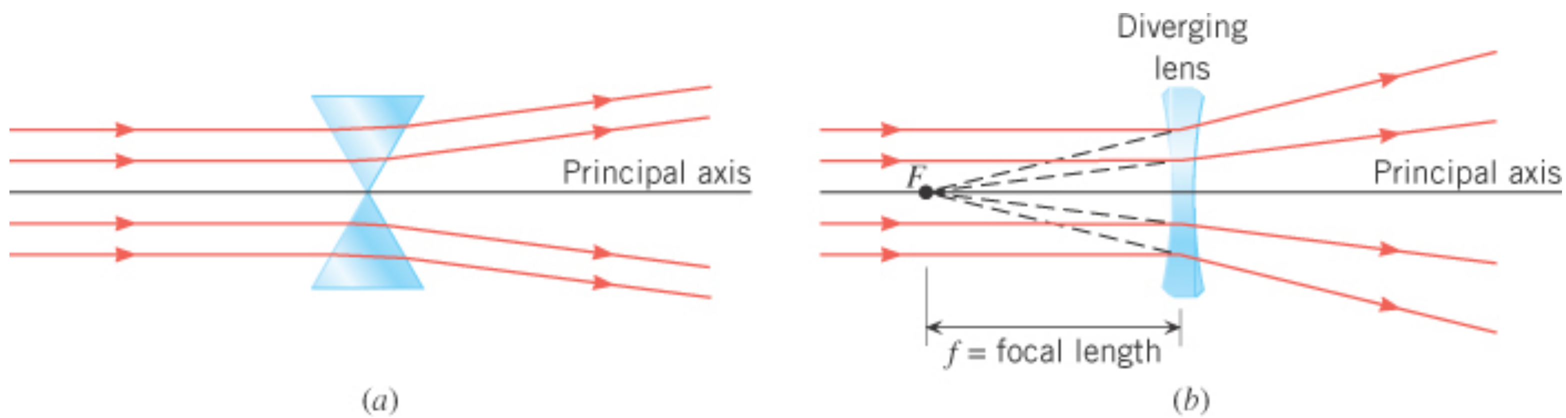
With a **converging lens**, paraxial rays that are parallel to the principal axis converge to the focal point, F. The focal length, f, is the distance between F and the lens.



Two prisms can bend light toward the principal axis acting like a crude converging lens but cannot create a sharp focus.

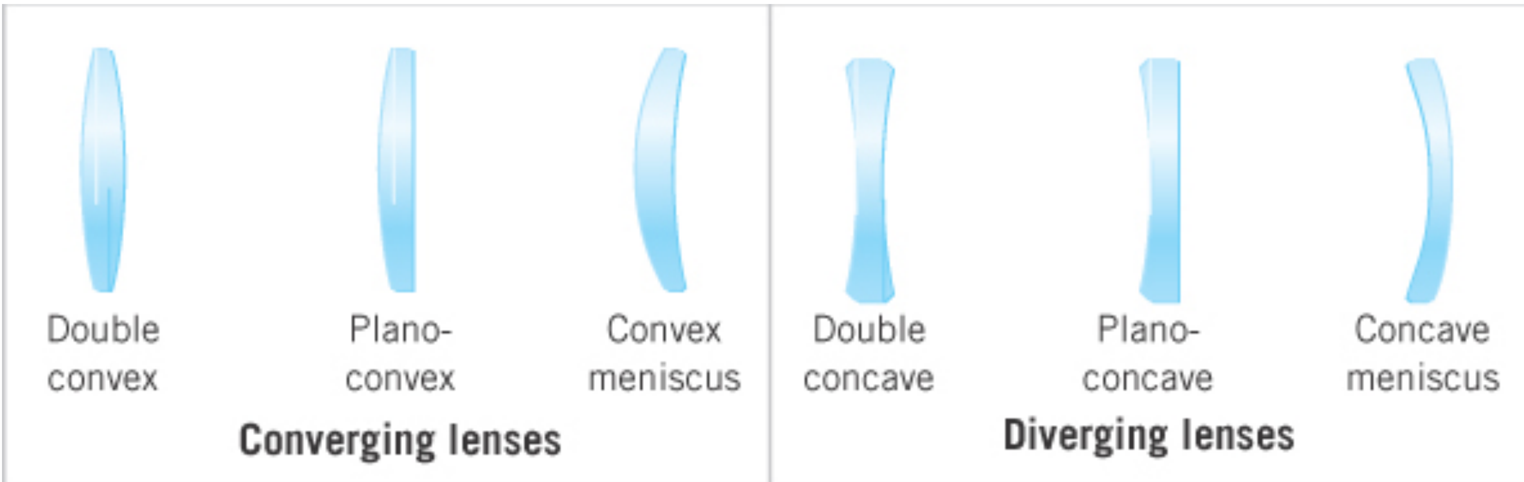
Lenses

With a **diverging lens**, paraxial rays that are parallel to the principal axis appear to originate from the focal point, F. The focal length, f, is the distance between F and the lens.



Two prisms can bend light away from the principal axis acting like a crude diverging lens, but the apparent focus is not sharp.

Lenses



Converging and diverging lens come in a variety of shapes depending on their application.

We will assume that the thickness of a lens is small compared with its focal length ➔ **Thin Lens Approximation**

RAY DIAGRAMS. Here are some useful rays in determining the nature of the images formed by converging and diverging lens.

Since lenses pass light through them (unlike mirrors) it is useful to draw a focal point on each side of the lens for ray tracing.

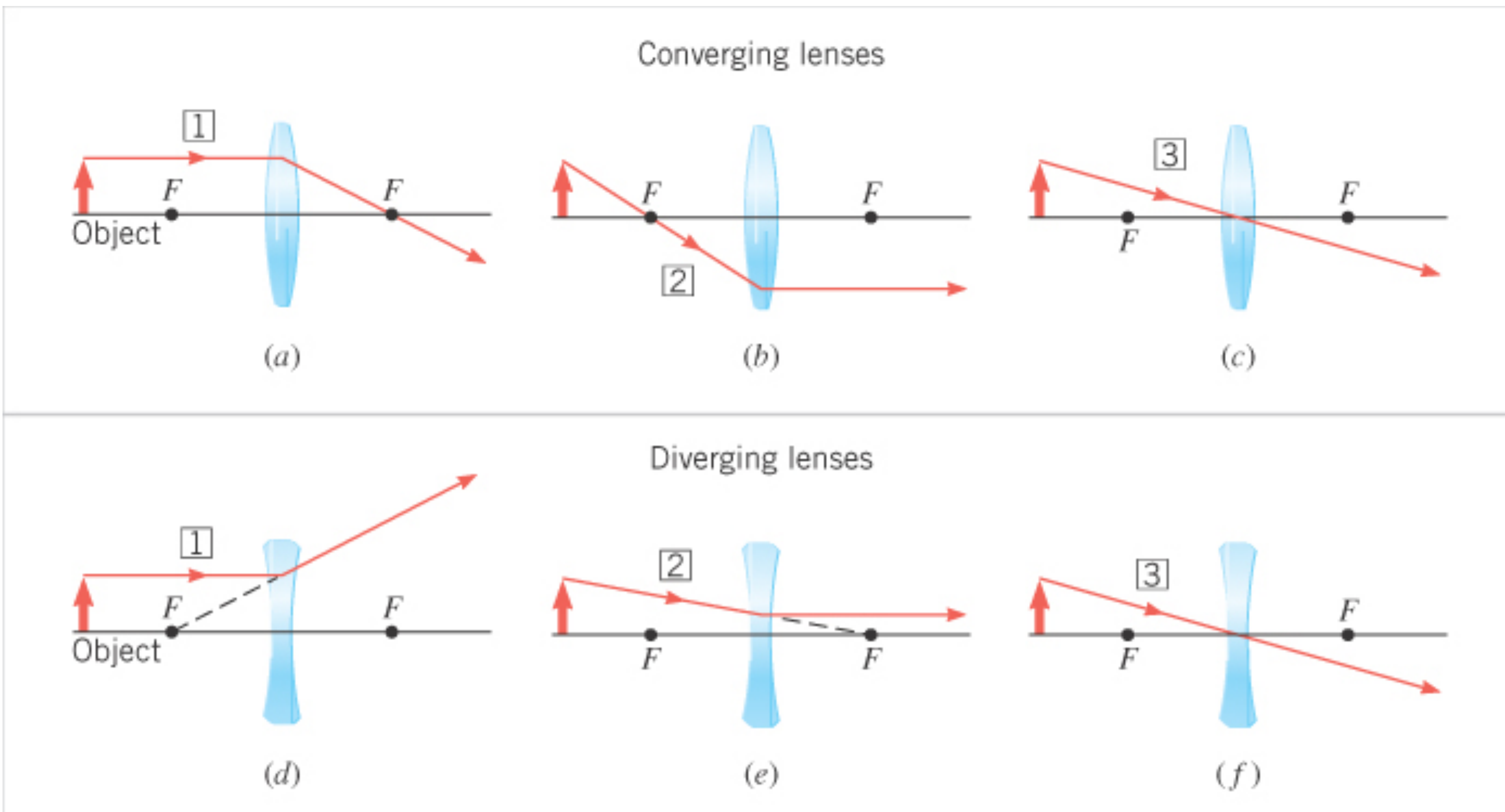
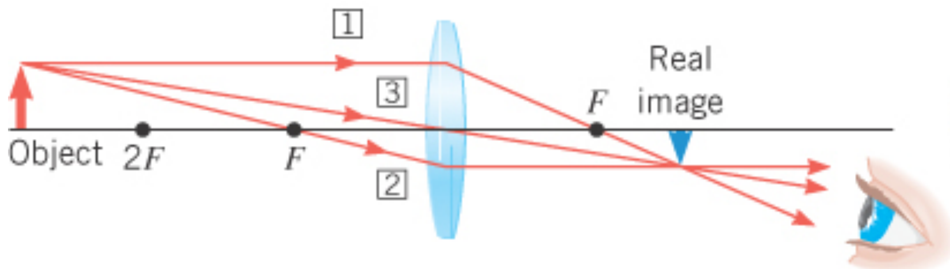
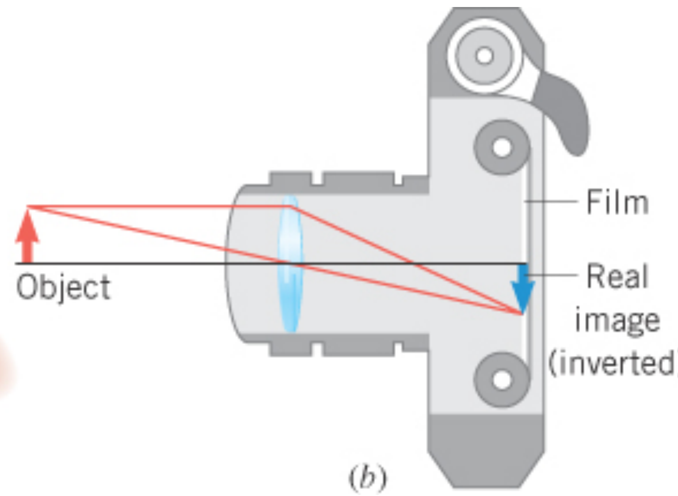


IMAGE FORMATION BY A CONVERGING LENS

$$d_o > 2f$$



(a)



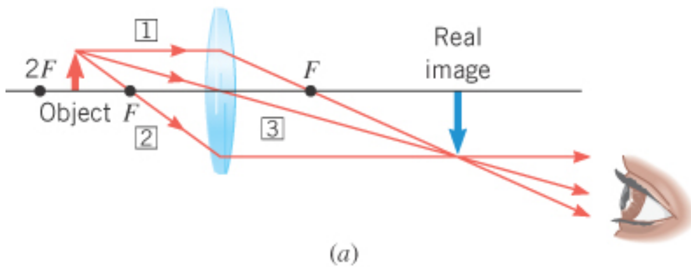
(b)

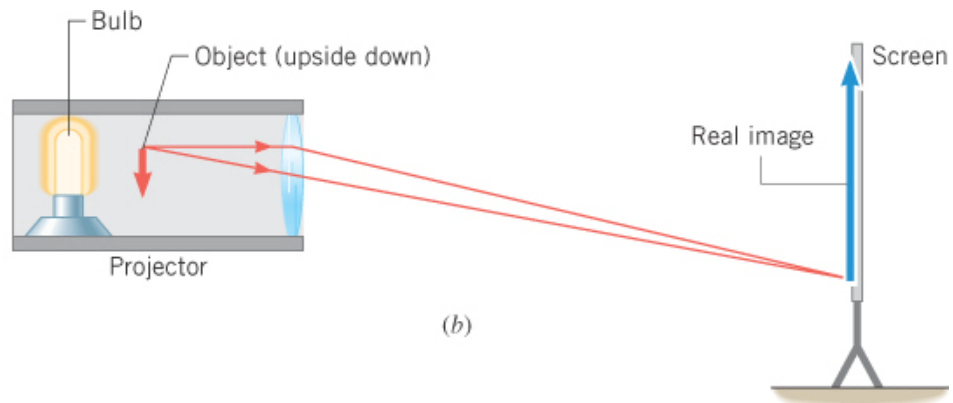
When the object is placed further than twice the focal length from the lens, the real image is inverted and smaller than the object.

This is the configuration for a camera. The focal length of the lens system of a camera must be adjusted for a particular object distance so that the image distance is at the location of the film and thus the real image on the film is sharp (focused).

IMAGE FORMATION BY A CONVERGING LENS

$$2f > d_o > f$$



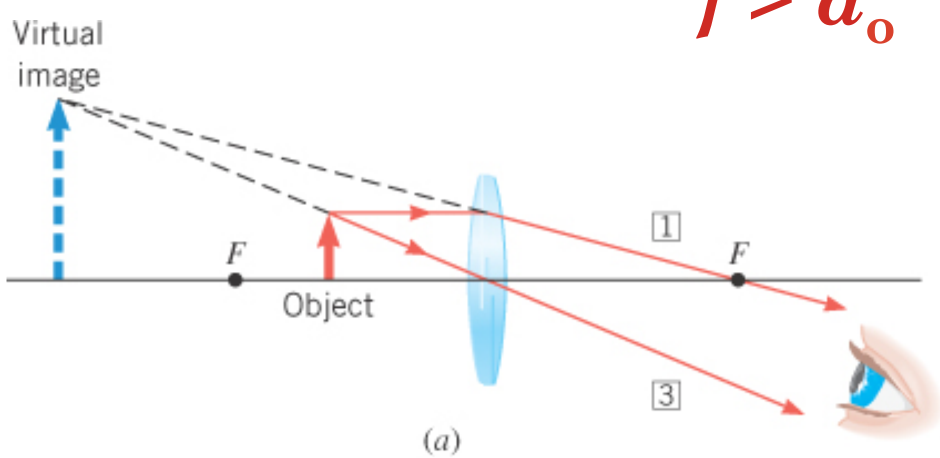


When the object is placed between F and 2F, the real image is inverted and larger than the object.

This is the configuration for a projector. Since you normally want the real image on the screen to be upright, the object (film or slide) is placed upside down in the projector.

IMAGE FORMATION BY A CONVERGING LENS

$$f > d_o$$

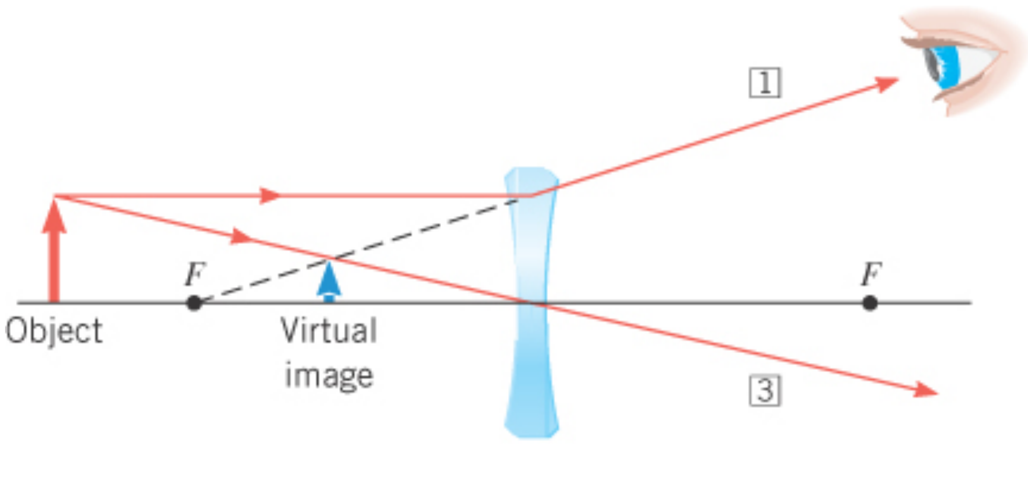


When the object is placed between F and the lens, the virtual image is upright and larger than the object.

This is the configuration for a magnifying glass. The magnifying glass must clearly be positioned so that the object distance is less than its focal length

IMAGE FORMATION BY A DIVERGING LENS

all d_o

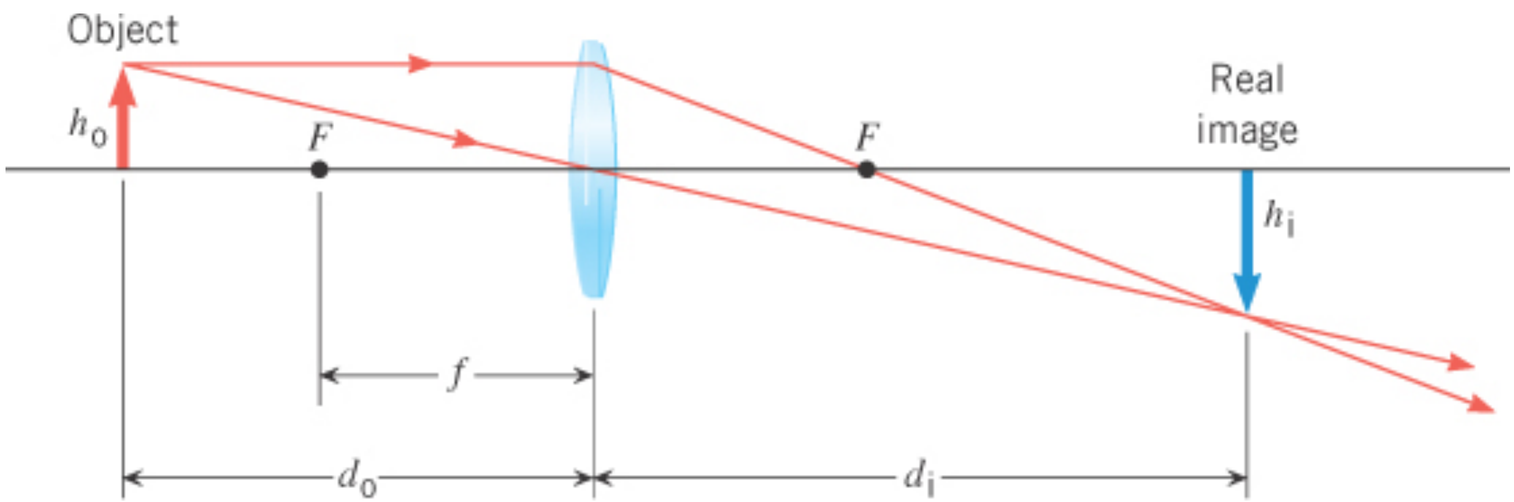


(a)

(b)

A diverging lens always forms an upright, virtual, diminished image.

The Thin-Lens Equation and the Magnification Equation



Thin lens equation

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

Magnification equation

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

These equations are identical to the mirror equations!

The sign conventions are similar to those for mirrors, but there are a few differences……

Summary of Sign Conventions for Lenses

f is + for a converging lens.

f is – for a diverging lens.

d_o is + if the object is to the left of the lens.

d_o is – if the object is to the right of the lens.*

d_i is + for an image formed to the right of the lens (real image).

d_i is – for an image formed to the left of the lens (virtual image).

m is + for an upright image.

m is – for an inverted image.

* can occur in the case of imaging with more than one lens.