Thin Lenses

In order to understand lenses, one must first define some terms.

Some Definitions

- The **Focal point** is the location at which rays parallel to the optical axis of an ideal mirror or lens converges to a point.
- The **focal length** is the distance between the focal point and the middle of the lens. It will be represented by **F**. You will also see **2F** being mentioned. **2F** just refers to two times the focal length.
- The distance from the center of the lens to the object will be referred to as $\mathbf{d_o}$.
- The distance from the center of the lens to the image will be referred to as $\mathbf{d_i}$.
- A **Real Image** is an optical image at which rays from the object converge. It is **inverted** or flipped upside down.
- A **Virtual Image** is a point from which Light rays appear to converge without actually doing so. It is **upright** or in the same direction as the object.
- A **concave lens** is a lens thinner in center than edges and is diverging.
- A **convex lens** is a lens thicker in the center than at the edges and is converging.

Ray diagrams are drawings of the different situations for lenses. These drawings are the different cases for a double convex lens.

For the ray diagrams, assume that the lenses are thin. We assume this because we do not want the thickness of the lens to affect the bending of the rays. Although the rays do bend when they enter and leave the lens, it is miniscule and for the most part can be neglected.

From http://library.thinkquest.org/C003776/ingles/course/lenses.htm

Ray diagrams for a double convex mirror

Object is at Infinity

>>>F

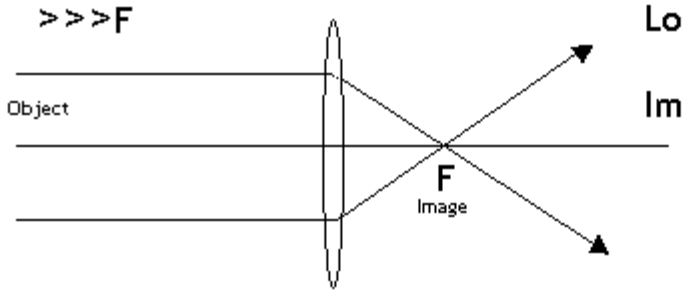

Image is Real and Located at F

Image is a point.

Object is further than 2F

>2F

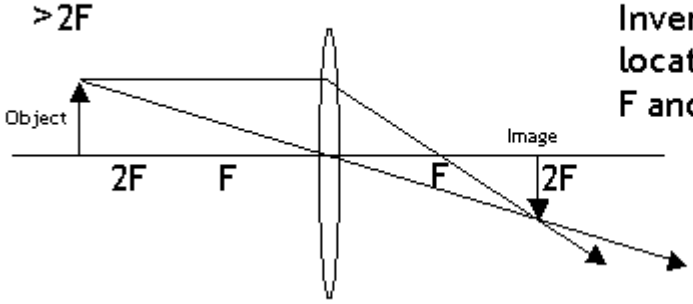

Image is Real Inverted and smaller, located between F and 2F

Object is at 2F

= 2F

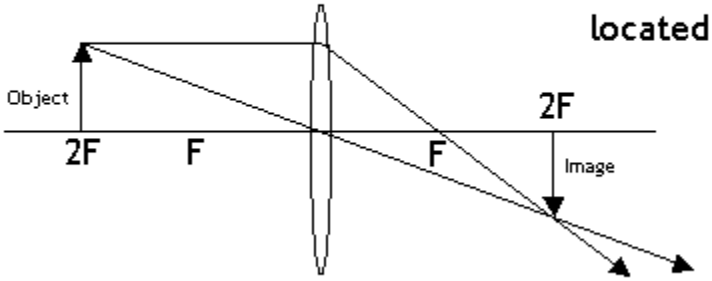

Image is Real and Inverted
The same size and located at 2F

Object is between F and 2F

F < Object < 2F

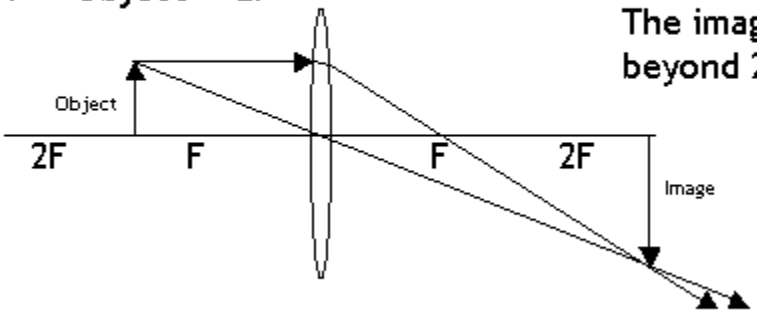

Image is Real, Magnified, and Inverted.
The image is located beyond 2F.

Object is at F

= F

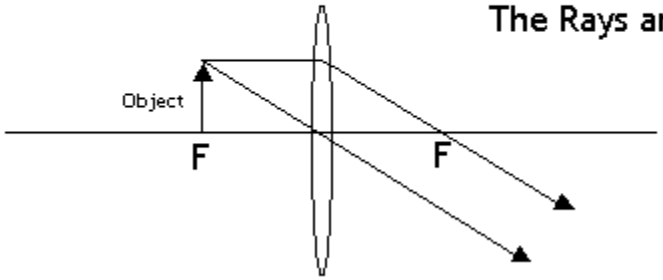

Image:
There is no Image
The Rays are Parallel

Object is between F and the Lens

< F

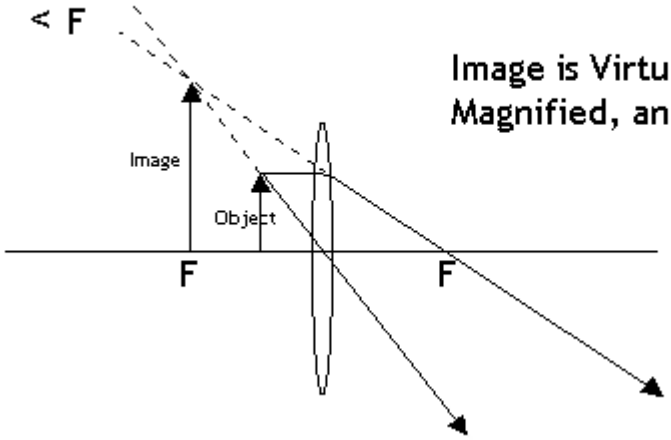

Image is Virtual, Magnified, and Upright.

Equations used with lenses

It is important to remember your signs when using these equations. An object which is to the left of the lens will have a positive sign. An image to the right of the lens will also carry a positive sign.

Lens Equation:

$$\mathbf{1/f = 1/d_i + 1/d_o}$$

Magnification equation:

The magnification of an object is equal to the ratio between the size of the image and the size of the object.

$$\mathbf{s_i/s_o = -d_i/d_o}$$

Example Problem:

A convex lens has a focal length of 30cm. A glass figurine that is 2cm tall, is placed 40cm from the lens. 1) Where is the image located? 2) What is the magnification? 3) What is the size of the image formed?

Solve the problem before viewing the solution. Show Work:

Solution

1) Find the distance of the image

Given:

$F = 30cm$

$D_o = 40cm$

Equation: $1/f = 1/d_i + 1/d_o$

$1/30 = 1/d_i + 1/40$

$1/d_i = 1/30 - 1/40$

$1/d_i = 1/120$

$d_i = 120cm$

2) Find the magnification

Given:

$D_o = 40cm$

$D_i = 120cm$

Equation: Magnification $= d_i/d_o$

$= 120/40$

$= 3$ times

3) Find the size of the image

Given:

$S_o = 2cm$

$D_o = 40cm$

$D_i = 120cm$

Equation: $s_i/s_o = -d_i/d_o$

$S_i d_o = -d_i s_o$

$S_i = -(d_i s_o)/d_o$

$S_i = -[(120)(2)]/40$

$S_i = -6cm$ (The negative sign shows that the image is inverted)

* An alternative method of finding the size of the image would be to see that the magnification of the object is 3 times. Knowing that the size of the object was 2cm, the image must be 3 times of this or 6cm tall.

4) Check to see that your answer makes sense.

The problem gives the focal length as 30cm. This means that 2F= 60cm. The object, at 40cm, is between F and 2F. This is a Case 4 situation. This means that the image should be magnified, real, inverted, beyond 2F, and on the other side of the lens. The image is magnified (by 3 times, and it is 6cm tall). The distance of the image, at 120cm, is definitely beyond 2F (which is 60cm). We also know that the image is inverted (and therefore real) because we got a negative size for the image. So our solution checks out correctly.