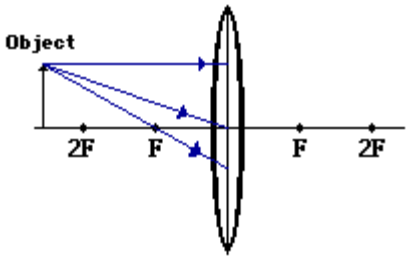
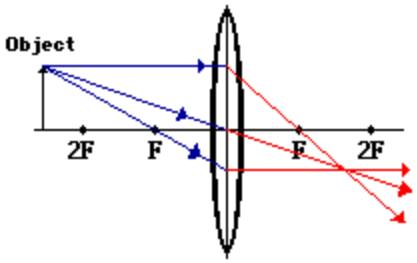
Tutorial: Ray Diagram for Convex Lenses

Here we describe the method of drawing a ray diagram for a convex lens, for which the object is located beyond the 2F point of the lens.



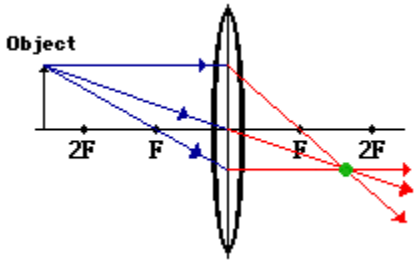
1. Pick a point o the top of the object and draw three incident rays traveling towards the lens.
    a. Draw one ray so that it passes through the focal point on its way to the lens.
    b. Draw a 2nd ray such that it travels parallel to the principal axis.
    c. Draw a 3rd ray such that it travels directly to the center of the lens.
    d. Place arrowheads on the rays to indicate their direction of travel.

2. Once these incident rays strike the lens, refract them according to the **three rules of refraction** for converging lenses.



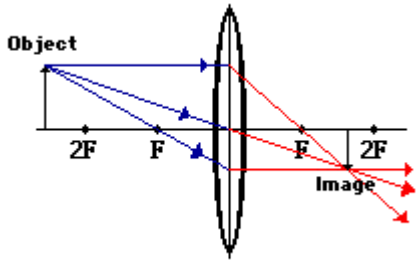
    a. The ray that passes through the focal point on the way to the lens will refract and travel parallel to the principal axis.
    b. The ray that traveled parallel to the principal axis on the way to the lens will refract and travel through the focal point.
    c. The ray that traveled to the center of the lens will continue in the same direction.
    d. Place arrowheads upon the rays to indicate their direction of travel.
    e. Extend the rays past their point of intersection.

3. Mark the image of the top of the object.



The image point of the top of the object is the point where all three refracted rays intersect. All three rays should intersect at exactly the same point. (Of course, the rest of the object has an image as well. This can be found by applying the same three steps to another chosen point.)

4. Repeat the process for the bottom of the object

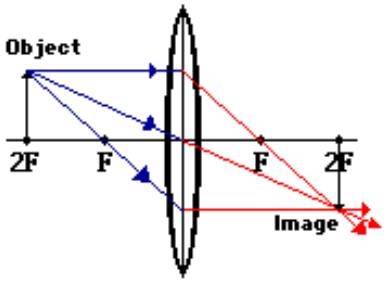


If the bottom of the object is located on the principal axes (as it does in this example), then the image of this point will also lie on the principal axis, and will be the same distance from the lens as the image of the top of the object. At

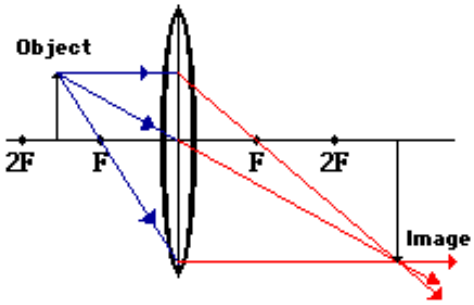
At this point the entire image can be filled in.

5. The ray diagram above illustrates that when the object is located at a position ***beyond*** the 2F point, the image will be located at a position between the 2F point and the focal point on the opposite side of the lens. Furthermore, the image will be inverted, reduced in size (smaller than the object), and real. This is the type of information that we wish to obtain from a ray diagram.

6. Practice drawing ray diagrams for the following two situations:
    a. The object is located at the 2F point (that is twice the focal length away from the lens)
    b. The object is located between the 2F point and the focal point F.



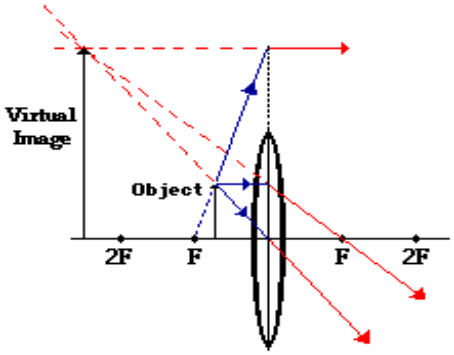
Ray Diagram for Object Located at 2F



Ray Diagram for Object Located Between F and 2F

It should be noted that the process of constructing a ray diagram is the same regardless of where the object is located. While the result of the ray diagram (image location, size, orientation, and type) is different, the same three rays are <u>*always*</u> drawn. The three rules of refraction are applied in order to determine the location where all refracted rays intersect.

7. Ray diagram for an object located in front of the focal point.



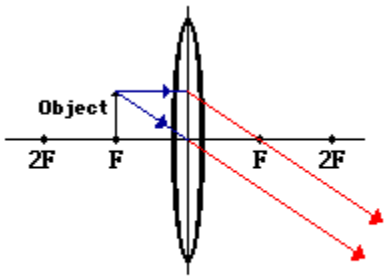
Ray Diagram for Object Located in Front of F

Eye

Observe that in this case the light rays *diverge* after refracting through the lens. In that case the image location can be found by tracing all light rays *backwards until they intersect*.
Since the light does not actually pass through the lens, the image is referred to as virtual image.

Observe, that when the object is located *in front of* the focal point of a converging lens, its image is an upright and enlarged image that is located on the same side of the lens as the object.

8. Ray diagram for an object located at the focal point.



Ray Diagram for Object Located at F
(an image is not formed)

For the case of the object being located at the focal point F, the light rays neither converge nor diverge after refracting through the lens. As shown in the diagram, the refracted rays are traveling parallel to each other. Thus, the light rays will not converge to form a real or virtual image, and there is no image. When an object is located at the focal point, there is no location in space, at which an observer can see from where all the refracted rays appear to be coming. Thus, and image cannot be found.