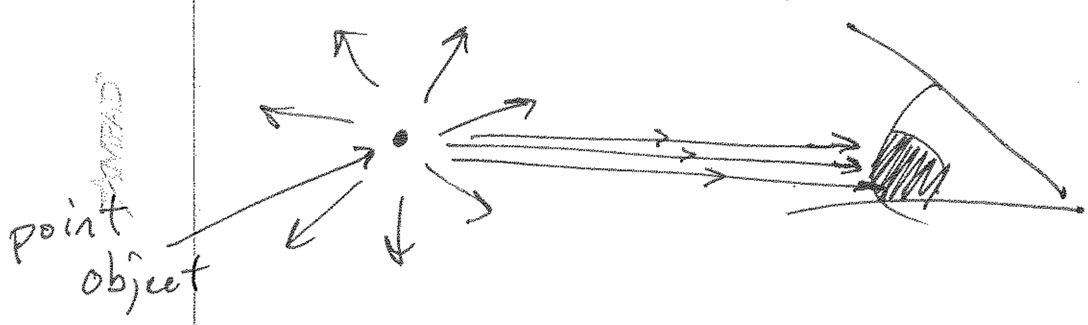
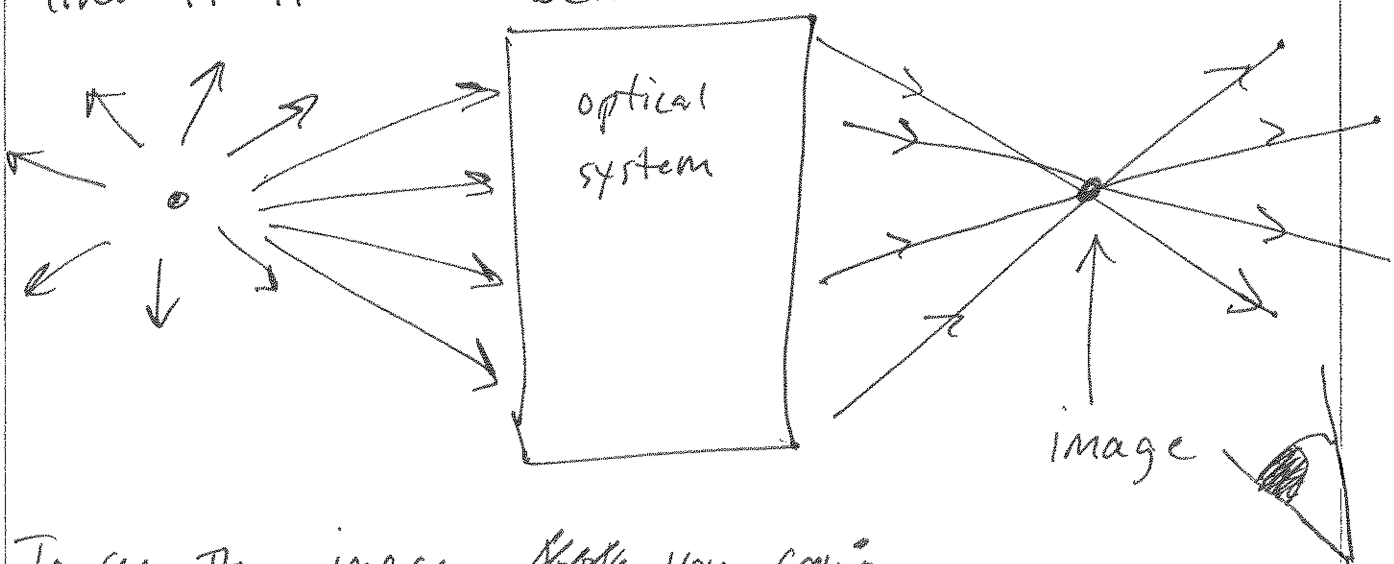
Imaging

Objects scatter light in all direction. The human eye collects only a small fraction of the light:

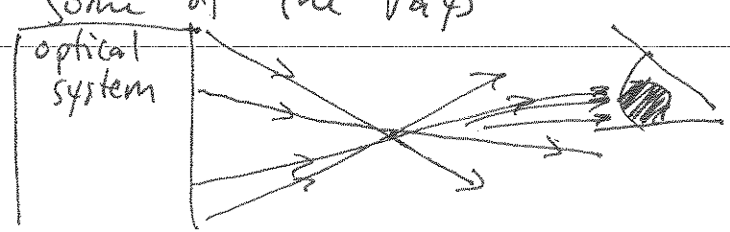


An optical system collects some of the light and re-directs the rays to a 2nd location, simulating what the object would look like if it were located there:

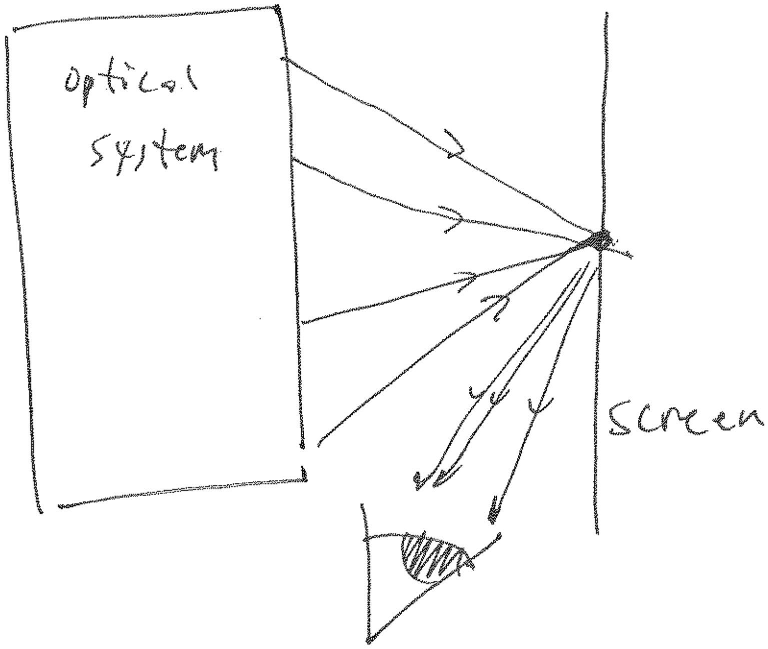


To see the image, you can:

i) look down the optical axis, so your eye directly collects some of the rays from the image.



2) Use a screen at the image location to re-scatter the light into all directions:

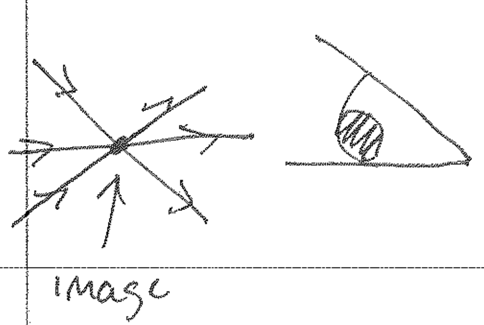


→ At a movie theatre, the screen allows everyone in the room to see the image.

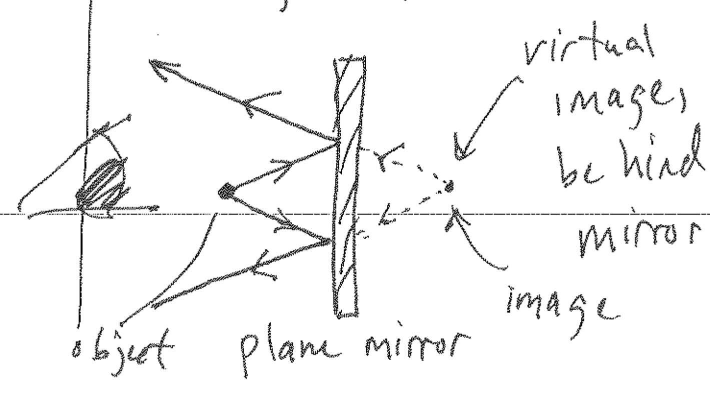
→ Without the screen, we would have to look directly into the projector (one person at a time.)

Two types of images: real and virtual

real image: rays pass through the image location



virtual image: rays appear to come from the image location, but do not:

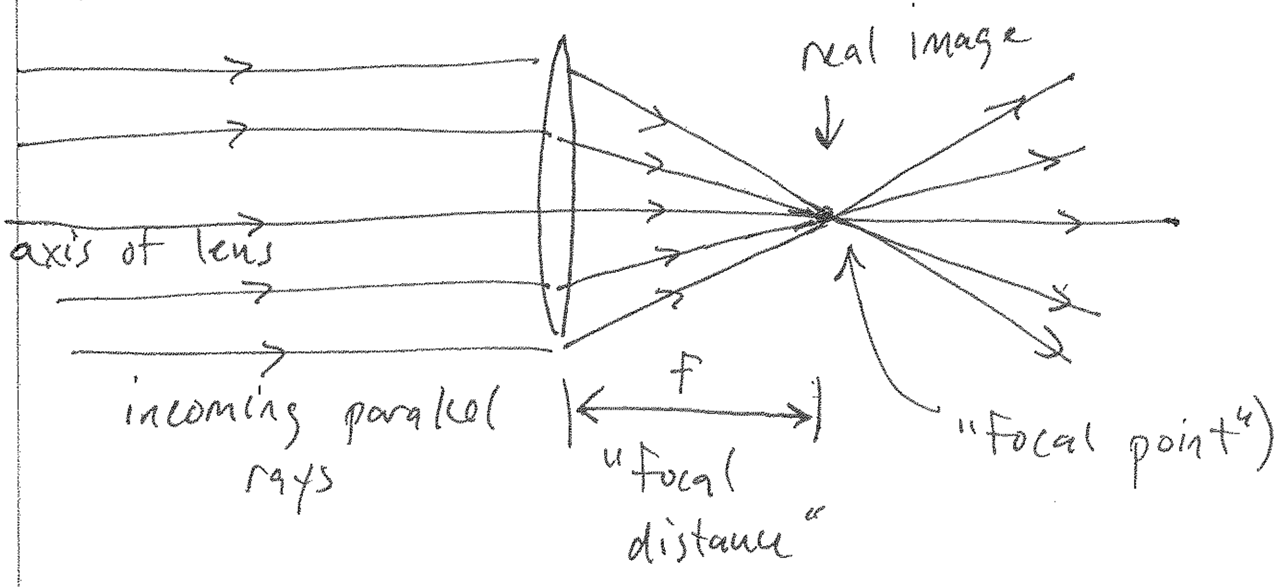


Thin Lenses

The simplest optical device that we will use in the lab is a thin converging (or convex) lens.

Converging Lenses take parallel rays and make them converge to a point (a real image.)

If the parallel rays are parallel to the axis of the lens, then the converging point is on the axis:



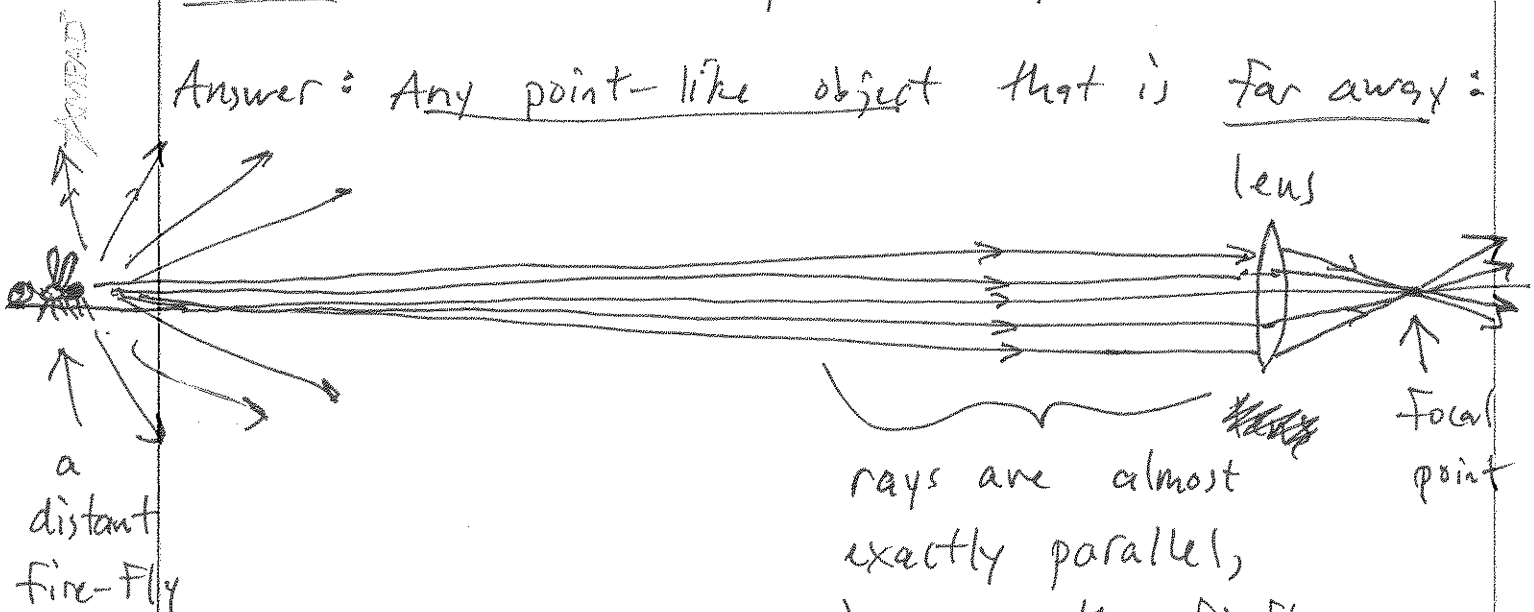
A fact, stated here without proof:

> All thin lenses have a focal point on each side, and the focal distance is the same on each side.

<u>Consequence</u>: It doesn't matter which side of the lens faces which way → the focal length is the same either way, so the behavior of the lens is the same.

<u>Question</u>: What creates parallel rays?

Answer: <u>Any point-like object</u> that is <u>far away</u>:

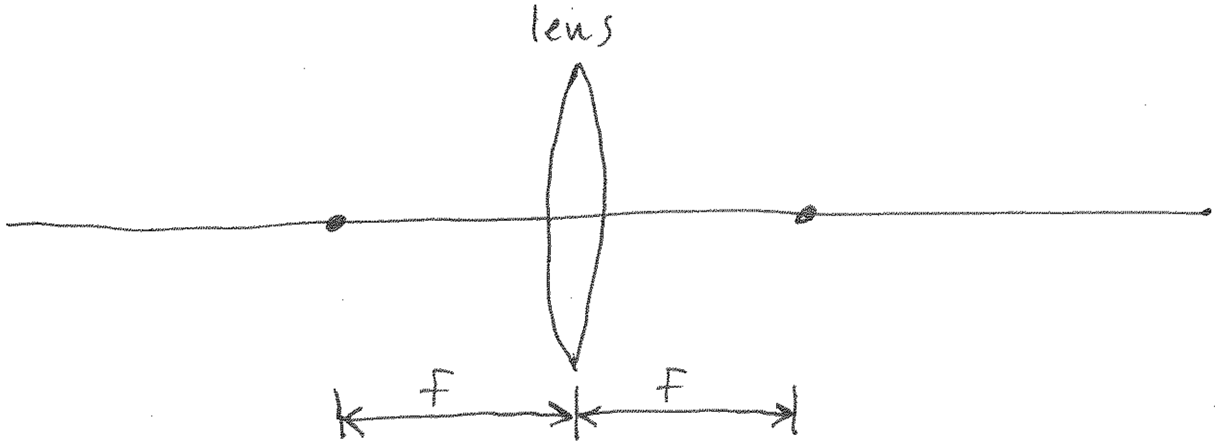


An even better example: <u>A star</u>.

<u>Principle Ray Diagram.</u>

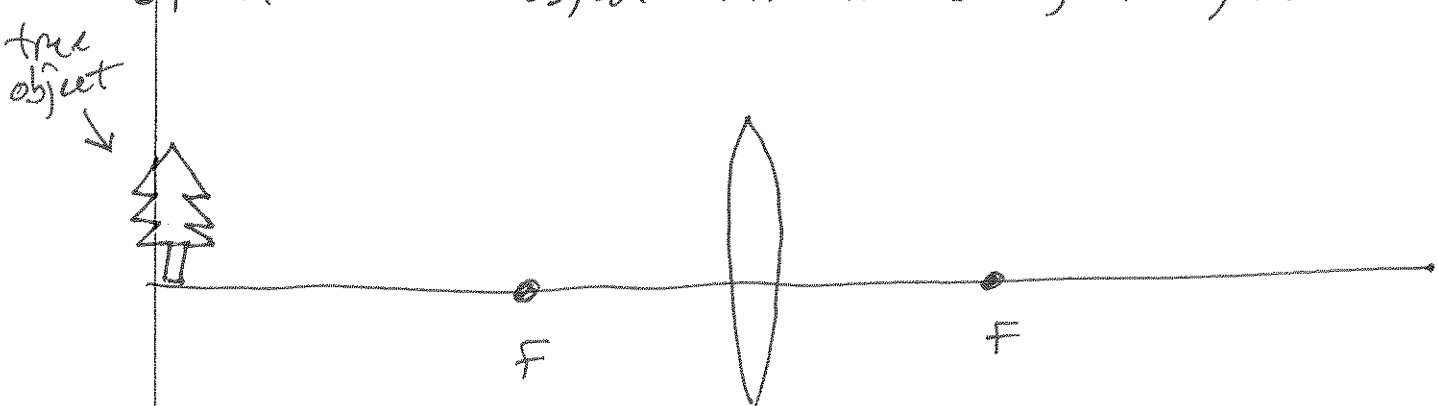
We can locate the image created by a thin converging lens using a geometric method: the principle ray diagram.

1) First draw the lens, its optical axis, and locate the focal points on both sides (must be the <u>same</u> distance from the lens)



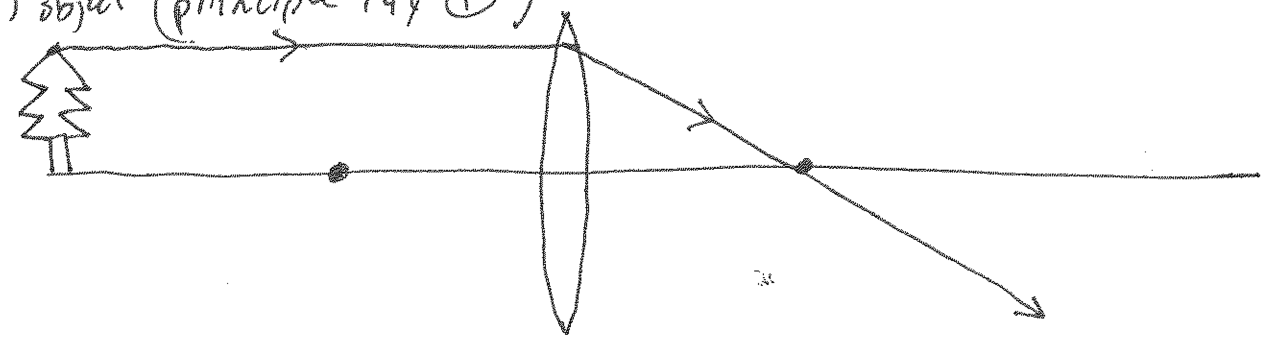
(we always ignore the thickness of the glass when considering thin lenses.)

2) Draw the object that is being imaged:



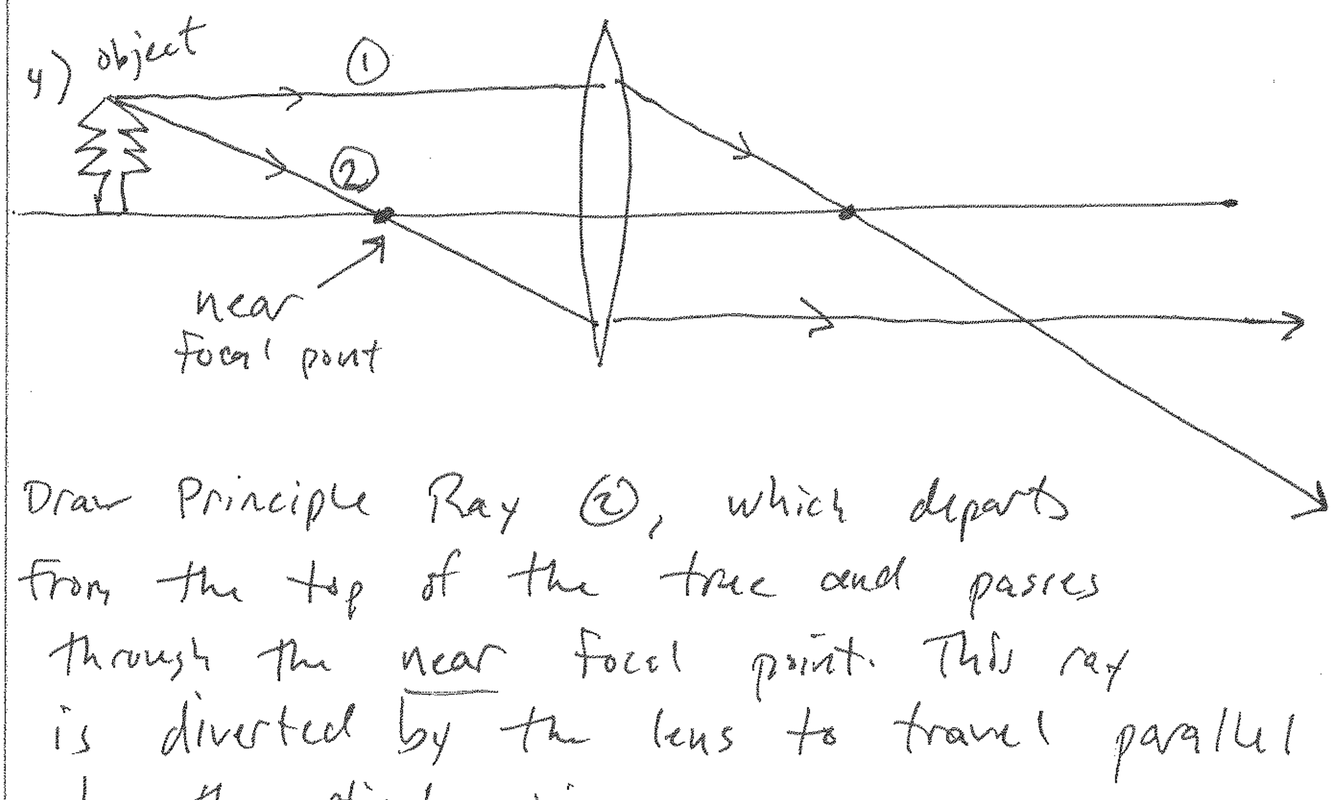
The base of the tree sits on the optical axis, and the <u>image of the base</u> will also be on the optical axis. Our goal is to determine <u>where the top of the tree</u> will be imaged.

3) object (principle ray ①)



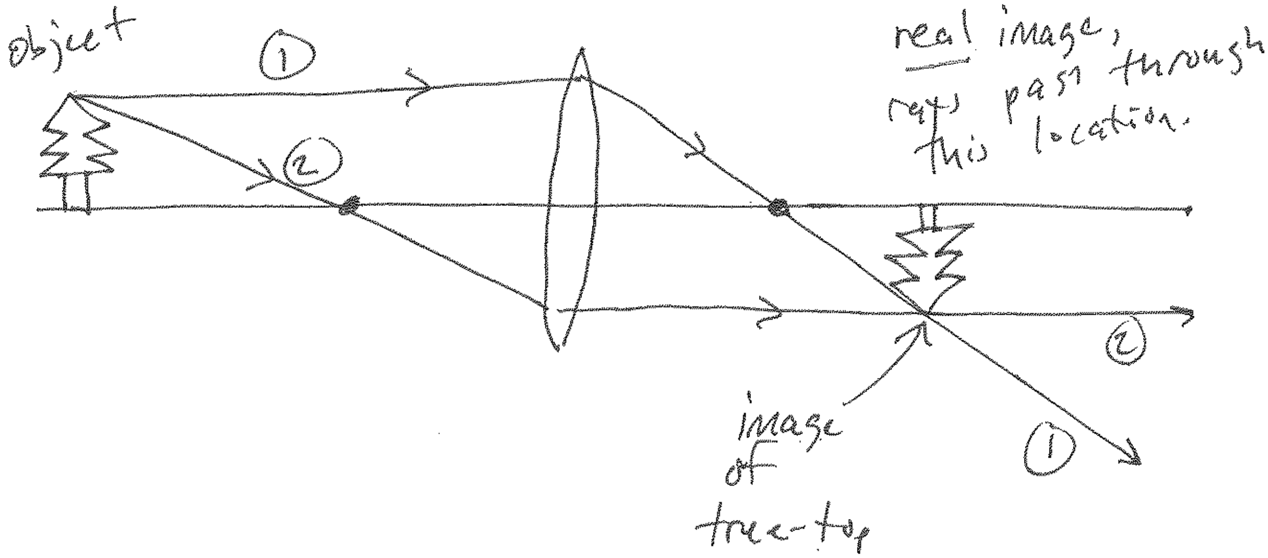
Draw principle ray ①, which departs from the top of the tree traveling parallel to the optical axis. This ray will be diverted by the lens to pass through the focal point on the other side.

4) object

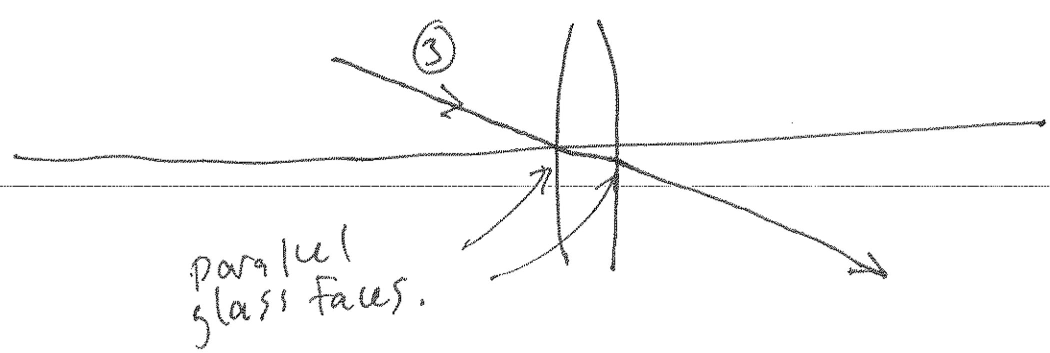


Draw Principle Ray ②, which departs from the top of the tree and passes through the near focal point. This ray is diverted by the lens to travel parallel to the optical axis.

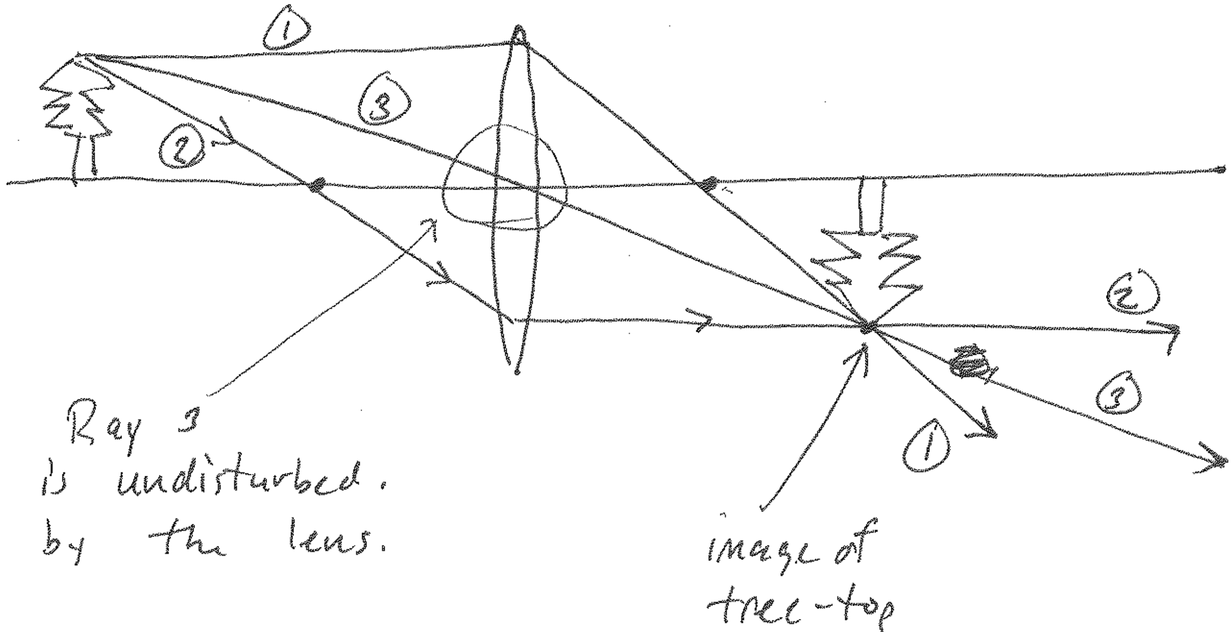
5) The location where ① and ② cross on the far side of the lens is the image location for the top of the tree. The bottom of the tree will be directly underneath it on the optical axis.



6) To confirm the image location, draw the 3rd principle ray, which passes through the center of the lens and is un-diverted. (because the two sides of the lens glass are parallel in the center, so the ray jogs over very slightly but does not bend.)



so all 3 rays look like:



Ray ③ should pass through the same point as Rays ① & ②.

Thin Lense Equation:

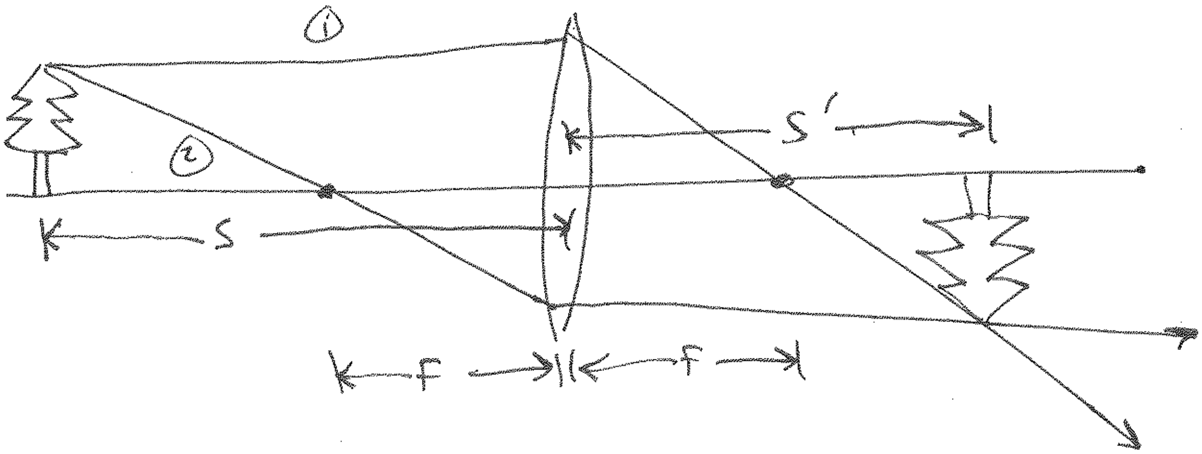
The location of the image can also be found using the thin lense equation:

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{F},$$

where s = object distance (positive when object is on the input side of the lense)

s' = image distance (positive when image is on the output side of the lense.

F = focal length, (positive for converging lenses)



The thin lense equation and the Principle Ray Diagram should always agree on where the image is located.

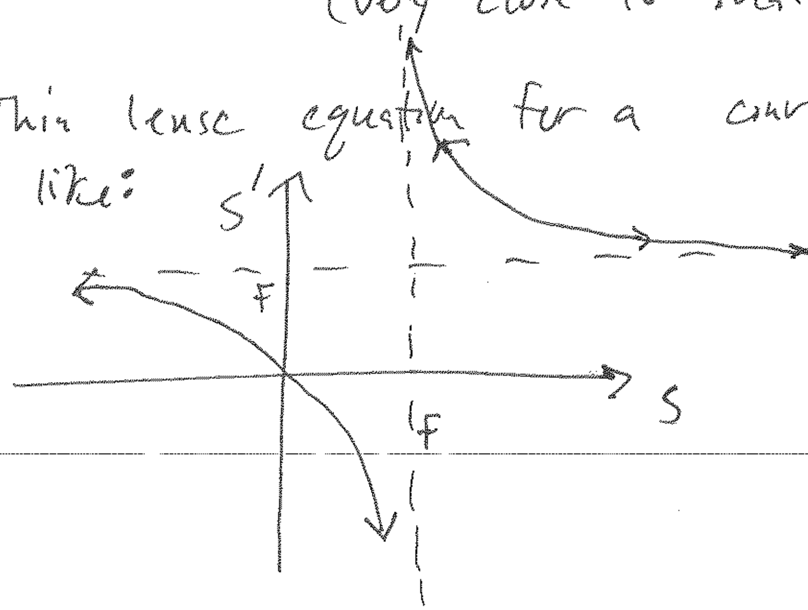
Ex: If tree object is located 10 focal lengths in front of lens, then tree image is located:

$$\frac{1}{(10F)} + \frac{1}{S'} = \frac{1}{F}$$

$$S' = \left(\frac{1}{F} - \frac{1}{10F}\right)^{-1} = \frac{10F}{9} = \frac{10}{9}F$$

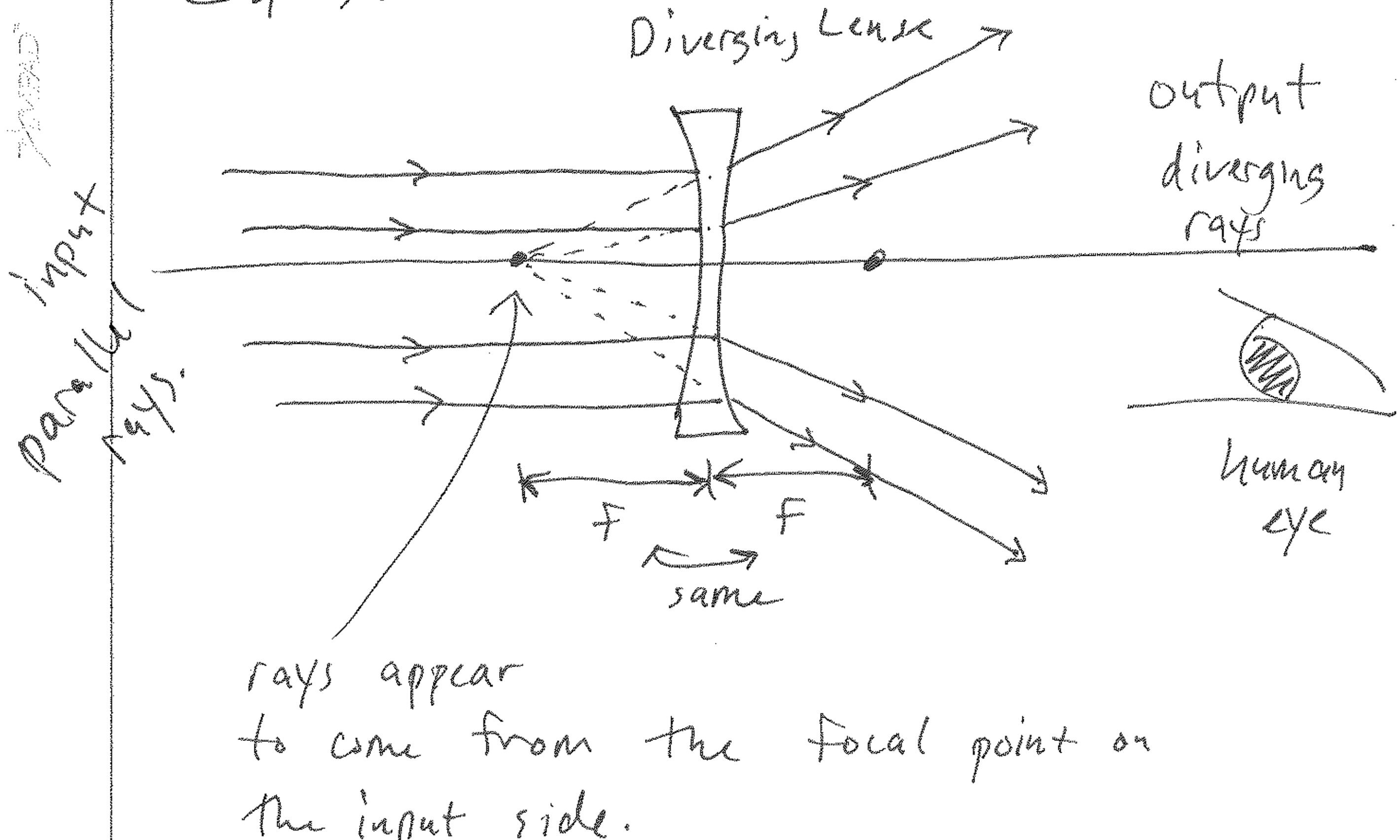
Object is $\frac{10}{9}$ focal lengths from lense. (very close to focal point.)

Graphically, Thin lense equation for a converging lens looks like:



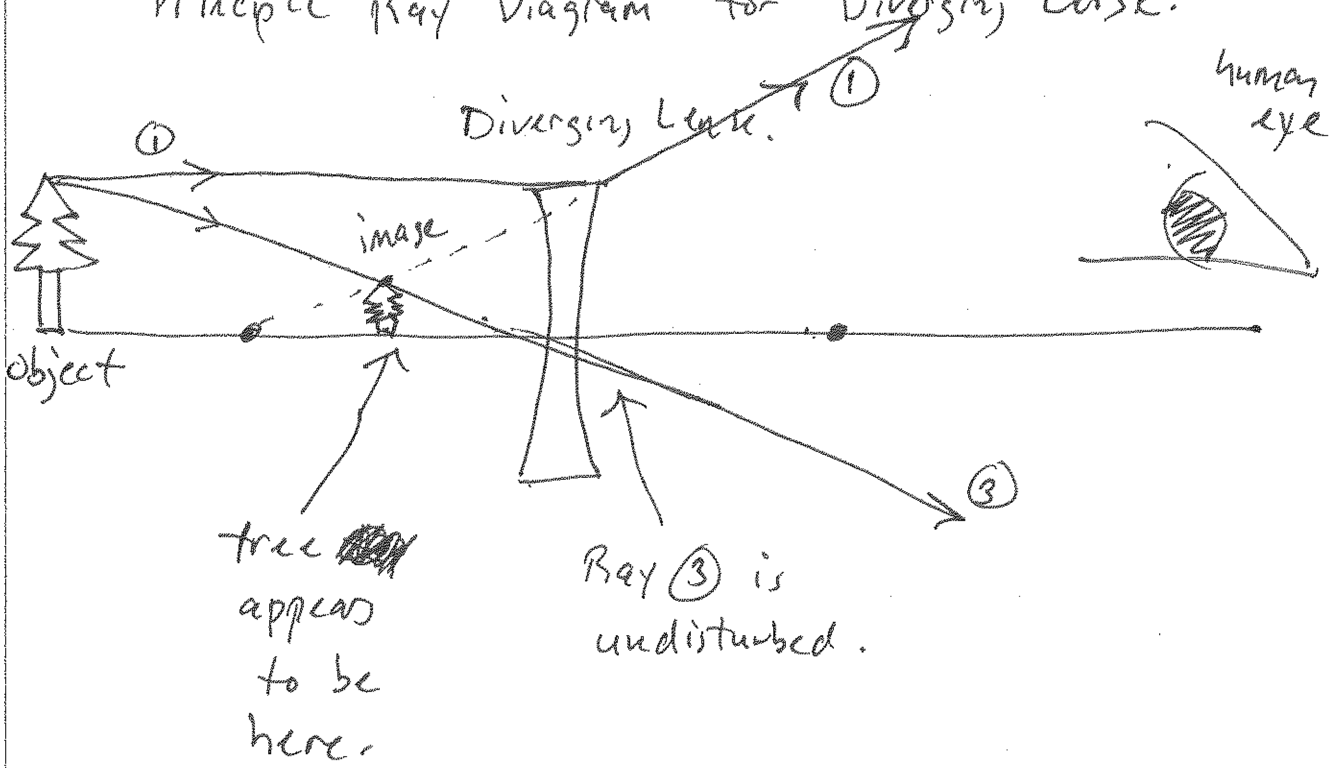
Diverging Lenses : negative focal length.

A Diverging Lense takes parallel rays and makes them appear to be spreading out from the focal point on the input side:



This is a virtual image : the rays do not actually pass through the near focal point.

Principle Ray Diagram for Diverging Lense.



Thin Lense Equation: $\frac{1}{s} + \frac{1}{s'} = \frac{1}{F}$

F is negative for diverging lense.

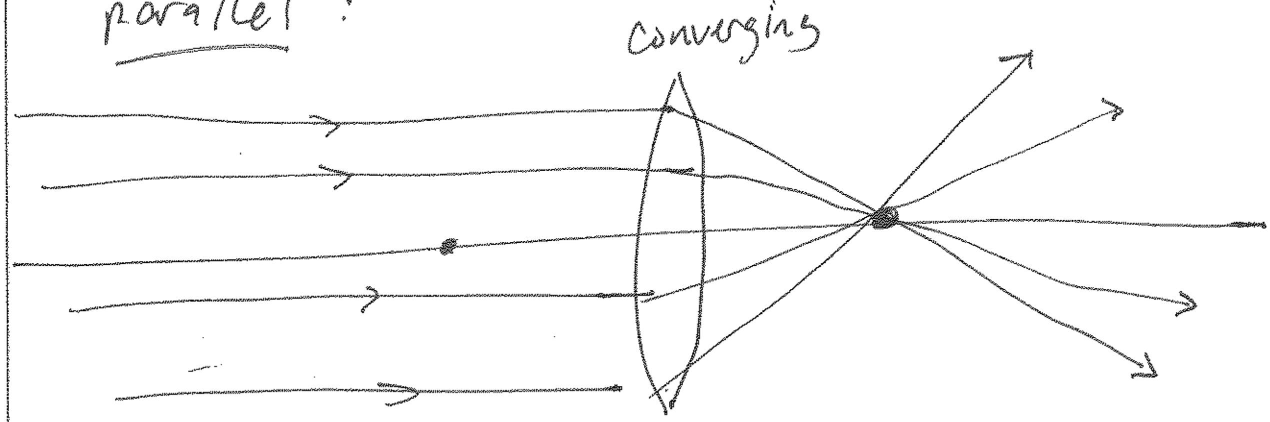
Example: Tree Object is 10 focal lengths away.

Then $\frac{1}{(10F)} + \frac{1}{s'} = \frac{1}{F} = \frac{-1}{|F|}$ because $F < 0$.

Then $s' = \left(\frac{-1}{|F|} + \frac{1}{10|F|} \right)^{-1} = \frac{-10}{9}|F|$

s' is negative, image is on the <u>input</u> <u>side</u> of lense.

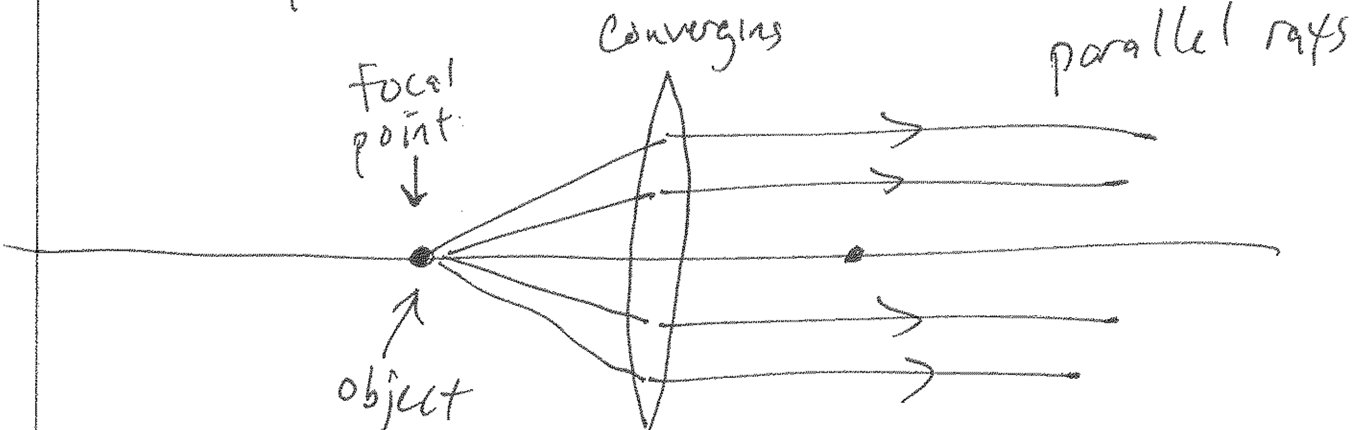
One more example: Object at infinity. Then $s \to \infty$, and the rays become <u>parallel</u>:



$$\frac{1}{\infty} + \frac{1}{s'} = \frac{1}{F} \implies \underbrace{s' = F}$$

image at focal point on output side.

Or, point object located at the near focal point:



$$\frac{1}{F} + \frac{1}{s'} = \frac{1}{F} \implies s' = +\infty,$$

which means parallel rays!