Lesson 29: Lenses

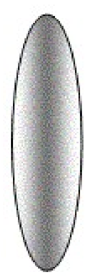
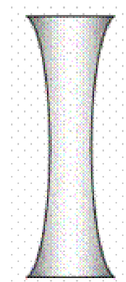
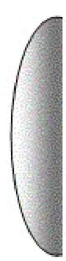
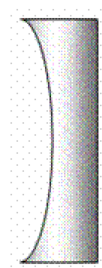
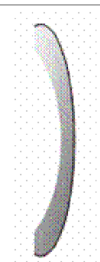
Remembering the basics of mirrors puts you half ways towards fully understanding lenses as well. The same sort of rules apply, just with a few modifications.

Keep in mind that for an object to be considered a lens it must be made of a transparent material that has an index of refraction higher than air.

- That way it will be able to refract the light as it passes through.
- Also, to get an image that isn't screwed up, we have to assume that the lens is thin.

The shape of a lens is named in a similar way to the naming of mirrors, it's just a little more complicated.

- All lenses are broken into two broad groups, depending on whether they focus light at a point (**converging** lens), or spread it out (**diverging** lens).
- **Converging** lenses are always **convex** in shape, which means the centre is thicker than the edges.
- **Diverging** lenses are always **concave** in shape, which means the edges are thicker than the centre.

Converging	Diverging
 Double Convex	 Double Concave
 Planoconvex	 Planoconcave
 Convex meniscus	 Concave meniscus

When drawing lenses in our sketches, we need to put in a **principle axis**, just like mirrors.

- You also need to add in a **principle plane**, a line that is perpendicular to the **principle axis** and runs length wise through the middle of the lens.
- We will be assuming that all refraction happens when the light reaches this principle plane.
  - Although this is not true, it makes our sketches a lot easier to do, and it is pretty accurate for lenses that are fairly thin.
- We still draw in the focal point, but now we do it on both sides.

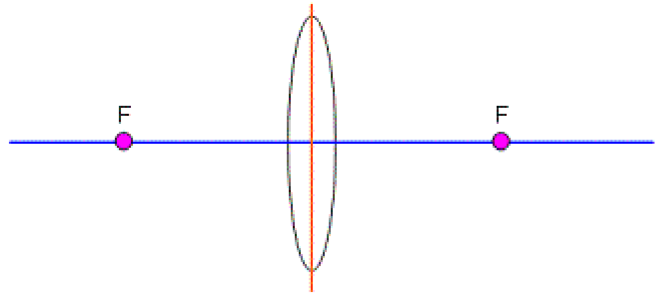


Illustration 1: Diagram showing a double convex lens.

Rule #1: Any ray through the focus will refract parallel to the principle axis.
Same basic idea as the rule you used for mirrors, but now the ray refracts and travels through the lens.

The light ray comes off of the object and goes through the focus. Notice that we did keep the ray moving in the same direction until it reached the **principle plane** in the lens. That's where we bent the light so that it would travel parallel to the **principle axis**.

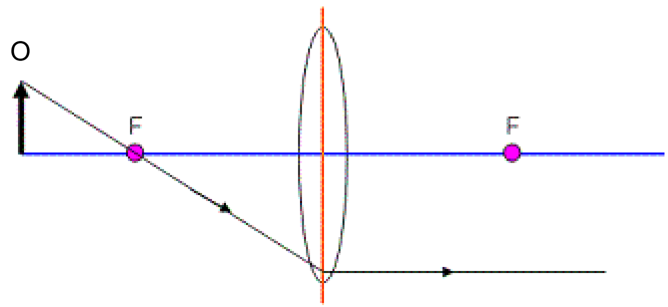


Illustration 2: Rule 1 goes through the focus.

Rule #2: Any ray parallel to the principle axis will refract so that it passes through the focus.

This ray starts off parallel to the **principle axis**. When it reaches the **principle plane**, it refracts so that it will go through the focus on the other side.

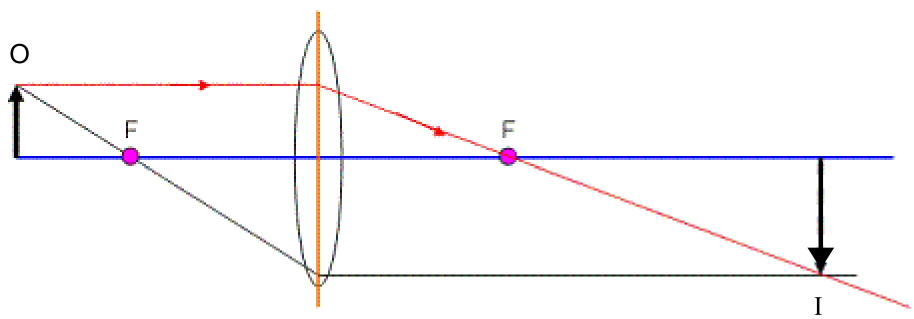


Illustration 3: Rule 2 is parallel to the principle axis.

Rule #3: Any ray that passes through the centre of the lens will come out the other side without any refraction.

By centre, we mean where the **principle axis** and **plane** cross. The ray goes straight through as if nothing was there. This is because as much as the ray is refracted one way on one side of the lens, it will be refracted back the other way on the other side of the lens.

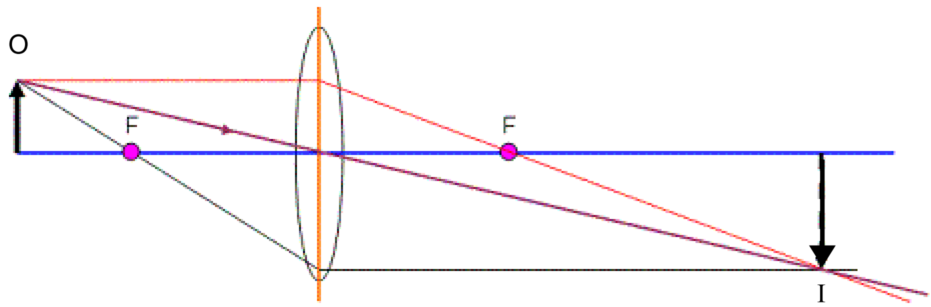


Illustration 4: A ray goes straight through the centre.

It looks like this ray agrees with our other two, so we must be doing ok!

- The image produced is...
  - enlarged
  - inverted
  - real (yup, rays of light *real*ly went through the lens and ended up on the other side.)

Let's look at an example using a diverging lens. We still use the same ideas, but we'll have to look at where the image will be formed carefully.

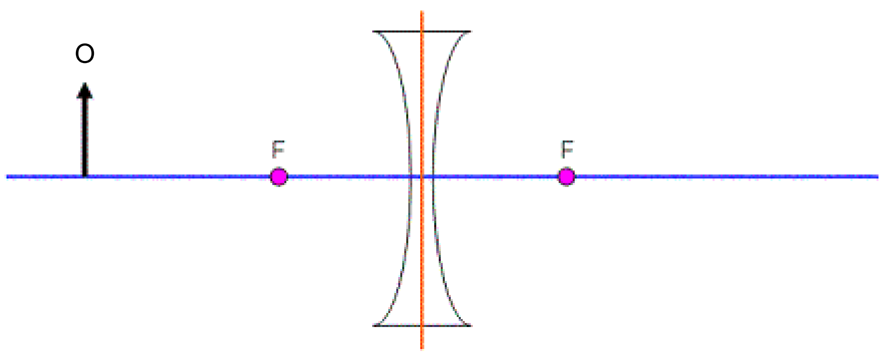


Illustration 5: A diverging lens with an object on the left hand side.

When we draw in the **first ray** parallel to the principle axis, it will hit the lens and diverge (be bent away). This must mean that if I extend the diverging ray back down as a dotted line, it will hit the focus on the object's side.

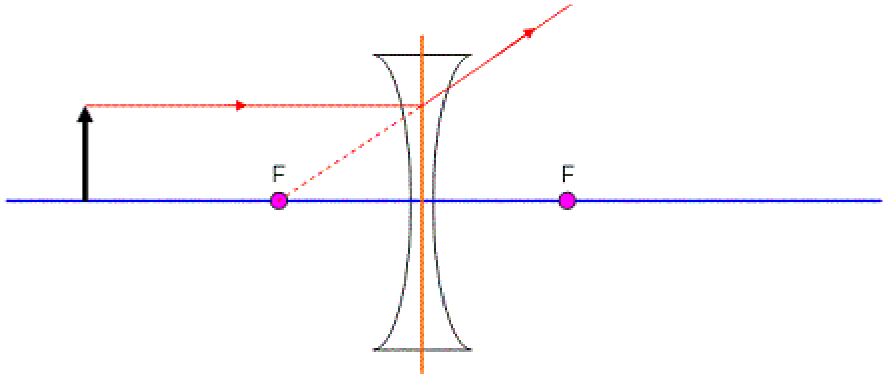


Illustration 6: The ray diverges (bends away on the other side) when it goes through the lens.

We can draw **another ray** that simply goes through the centre and see what happens…

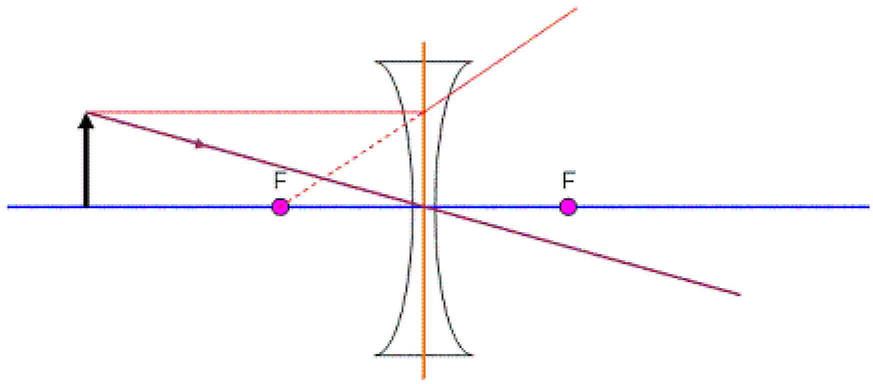


Illustration 7: A ray through the centre still goes straight through.

Notice where **this line** crosses the dotted line from the **first ray**? That's where my image will appear. Since one of the rays is not truly there, the image will be virtual.

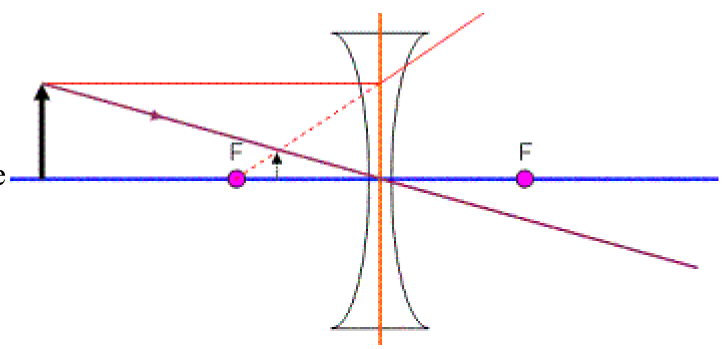


Illustration 8: Showing the virtual image that is produced.

You can use the same formulas as you did for mirrors to do calculations with mirrors. Just keep the following rules in mind (they're the same as the ones for mirrors…)

Ultra-Special Notes for Signs Using the Mirror Equation:

Like mirrors...

- a **converging** lens has a **positive focal length**
- a **diverging** lens has a **negative focal length**.

The object is always a positive distance, and we look at where the image appears relative to the object...

Images on the other side of the Lens (Real) → Positive +

Images on the same side of the Lens (Virtual) → Negative -

Example 1: A converging lens has a focal length of 0.22 m. If an object is placed 0.41 m in front of the lens, determine where the image will appear and identify its characteristics.

Since the lens is converging, the focal length will be +0.22 m. The object placed in front of the lens will have a positive distance from the lens of +0.41 m (objects are always positive distance).

$$\frac{1}{f}=\frac{1}{d_i}+\frac{1}{d_o}$$
$$\frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}$$
$$\frac{1}{d_i}=\frac{1}{0.22}-\frac{1}{0.41}$$
$$d_i=0.474737=0.47\text{m}$$

Since the distance to the image is positive, it is **real**. For a lens this means it is on the other side of the lens from the object.

To figure out the other characteristics of the image we will use the magnification formula.

$$m=\frac{-d_i}{d_o}$$
$$m=\frac{-0.47}{0.41}$$
$$m=-1.15789=-1.2$$

The negative sign on the magnification means the image is **inverted**. Since the magnification is greater than one, the image is **enlarged**.

Homework

p681 #1-2