

**PHY385-H1F Introductory Optics**  
Class 9 – Outline: Sections 5.1, 5.2

- Geometrical Optics Introduction
- Refraction at a Curved Surface
- Thin Lens Equation
- Focal Point
- Focal Plane
- Images
- Magnification
- Lenses in Combination

Image Formation by a Converging Lens

**How an image is formed**

**Finger Vote!!!** 🙋

Two plane mirrors form a right angle. How many images of the ball can you see in the mirrors?

**Finger Vote!!!** 🙋

air  
water

A fish swims below the surface of the water. An observer sees the fish at:

1. a greater depth than it really is.
2. its true depth.
3. a smaller depth than it really is.

**Finger Vote!!!** 🙋

air  
water

A fish swims *directly* below the surface of the water. An observer sees the fish at:

1. a greater depth than it really is.
2. its true depth.
3. a smaller depth than it really is.

**Image Formation from a Plane Surface**

A fish in the aquarium

The eye sees the image at distance  $d'$ .

Object    Image

Actual rays    Refraction

$d'$

Diverging rays appear to come from this point. This is a virtual image.

**Image formation at a spherical interface**

A line through C is normal to the surface.

$$\frac{n_1}{s_o} + \frac{n_2}{s_i} = \frac{n_2 - n_1}{R}$$

$R$  is positive means surface is convex toward the object  
 $R$  is negative means surface is concave toward object  
 $s_o$  is positive means object is to the left of interface  
 $s_i$  is positive means image is real, to the right of interface

**Lensmaker's Formula**

The image of the first surface is the object for the second surface.

$$\frac{1}{s_{o1}} + \frac{1}{s_{i2}} = (n - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$$

**Converging Lens**

**NOTE:** Focal length is defined for initially *parallel* rays.

**Diverging Lens**

**Virtual Focal Point**  
 Rays appear to emerge from Virtual Focal Point

**Finger Vote!!!**

What will happen to the rays emerging to the right of the lens if the face is moved a little *closer* to the lens?

1. They will remain parallel.
2. They will diverge (spread out).
3. They will converge (toward a focus).

**Finger Vote!!!**

What will happen to the rays emerging to the right of the lens if the face is moved a little *further away* from the lens?

1. They will remain parallel.
2. They will diverge (spread out).
3. They will converge (toward a focus).

All the rays leaving one point in the object plane (P) are refracted by the lens and converge to one point in the image plane (P').

**The Thin Lens Equation:** 
$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

$f$  is positive for a converging lens  
 $f$  is negative for a diverging lens  
 $s_o$  is positive means object is real, to the left of lens  
 $s_i$  is positive means image is real, to the right of lens  
 $s_i$  is negative means image is virtual, to the left of lens

### Ray Tracing With a converging thin lens

(a) Any ray initially parallel to the optical axis will refract through the focal point on the far side of the lens.

(b) Any ray passing through the near focal point emerges from the lens parallel to the optical axis.

(c) Any ray directed at the center of the lens passes through in a straight line.

### Ray Tracing With a diverging thin lens

Any ray initially parallel to the optical axis diverges along a line through the near focal point.

Any ray directed along a line toward the far focal point emerges from the lens parallel to the optical axis.

Any ray directed at the center of the lens passes through in a straight line.

### Thin Lens Combinations

The real image of the objective lens acts as the object for the eyepiece lens.

Virtual image seen through the eyepiece