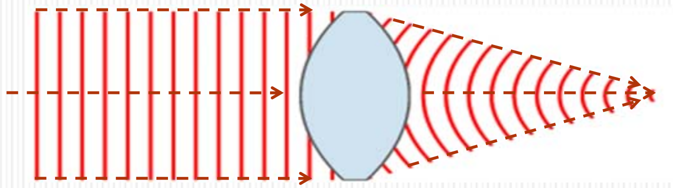
Mirrors, Lenses &Imaging Systems

145 Phys

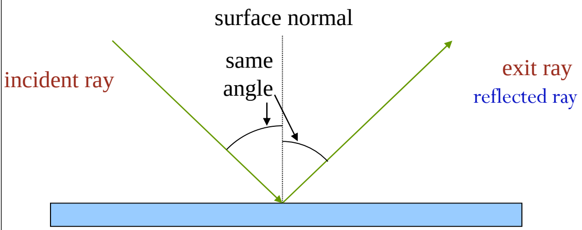
We describe the path of light as straight-line rays And light rays from a very distant point arrive parallel



24.1 Mirrors

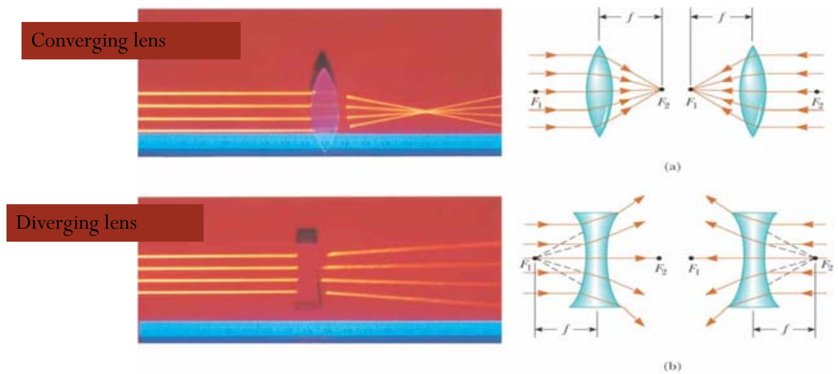
Standing away from a plane mirror shows a virtual (not real) image but with opposite direction.

The angle of incident ray is equal to the angle of reflected ray.



24.2 Lenses

Lenses are usually used to converge or diverge the light rays.
A converging lens bends the light rays toward its axis.
A diverging lens bends the light rays outward from its axis.



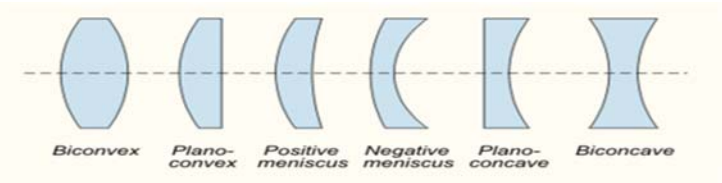
Lens classification

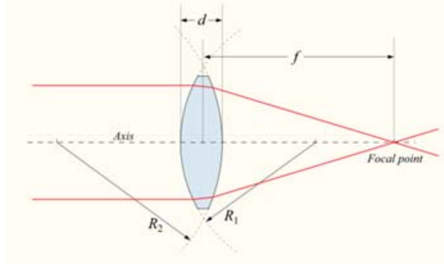
Lenses are either:

1- A **convex** surface (diverge light), has a positive radius of curvature. Convex lenses bring rays to a focus. The more curved the lens, the quicker the rays are focussed.

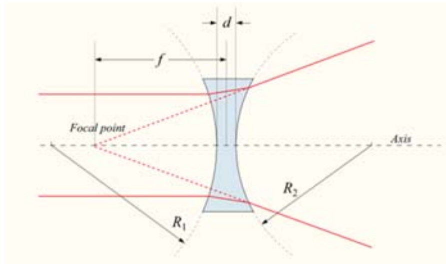
2- A **concave** surface (converge light), has a negative radius of curvature. Concave lenses make rays spread out. The more curved the lens ,the more the rays spread out.

3- A **plane** surface , has an infinite radius of curvature.





Positive (converging) lens



Negative (diverging) lens

Lensmaker's Equation

f is the focal length of the lens. Which is the distance for the center of the lens to the focal point.

The focal length is positive (+) for the converging lenses, and negative (-) for the diverging lenses .

A convex (concave) surface has a positive (negative) radius of curvature. A plan surface has an infinite radius of curvature.

The focal length depends on the refraction index (n)of the lens and its shape (i.e. on the radii of curvature R_1 and R_2)

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

n is the relative index of refraction :

$n = n(\text{lens}) / n(\text{medium})$

Example: 24.1

Lens made from glass with a refraction index of 1.5. Find the focal length if there are

(a) tow convex surface with radii of curvature 0.1 m and 0.2 m.

(b) one plane surface and one concave surface of radius 4 m.

Example: 24.2

What is the focal length of the lens in Example 24.1a if it is placed in water? The refraction index of the water is 1.333.

Quiz (24.1)

An object 4 cm high, is 20 cm in front of a thin convex lens of focal length +12 cm. Determine the position and height of its image.

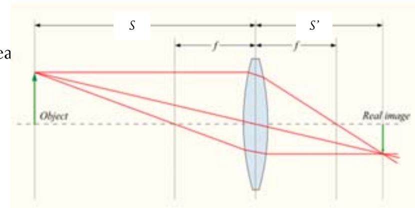
Summary
Light travel in straight lines.
There are real and virtual images.
Any lens defined by its refraction index and radius of curvature.
Lensmaker's equation $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$

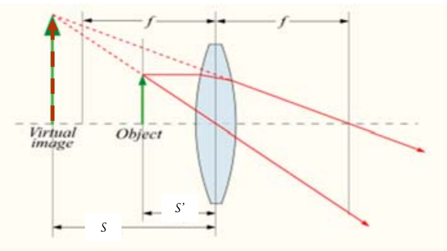
24.3 Imaging Formation

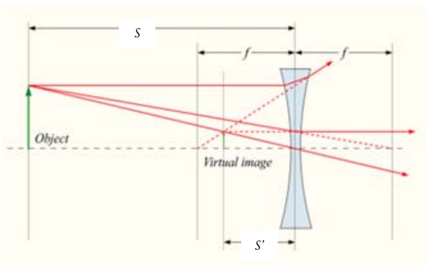
Images may be real or virtual

Real Image

Image is made from "real" light rays that converge at a rea focal point so the image is REAL
Can be projected onto a screen because light actually passes through the point where the image appears
Always inverted





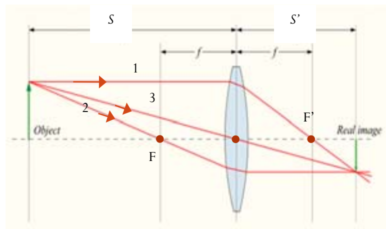


Virtual Image

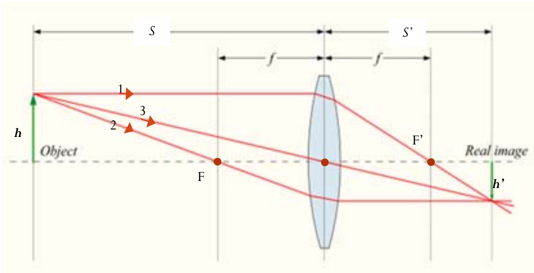
"Not Real" because it cannot be projected
Image only seems to be there!

Graphical or ray-tracing

We use the following conventions in the graphical or ray tracing approach to locating the image:
1- Light always goes form left to right.
2- Real objects are to the left of the lens, and real images to the right.
3- Virtual images are to the left of the lens, and virtual objects to the right.



The three numbered rays in the diagram are drawn from the arrowhead as follows:
1- The ray (1) leaving the arrowhead parallel to the axis is deflected by the lens and pass through the focal point **F'**.
2- The ray (2) going through the focal point **F** emerges from the lens parallel to the axis.
3- The ray (3) directed at he center of the lens is undeflected. (**Why**?)

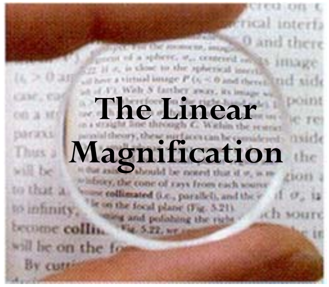


S and ***S'*** are the distance of the object and its image from the center of the lens along the axis respectively , while h and h' are the height of the object and its image respectively. And we adopt the following:

1- ***S*** is positive for a real object, negative fro a virtual object.

2- ***S'*** is positive for a real image, negative for a virtual image.

3- The object height ***h*** is positive if it points above the axis and negative if it points below the axis.



The linear magnification (***m***)is the ratio of the image and object heights. The linear magnification is positive when the image is erect and negative when the image is inverted.

$$m = \frac{h'}{h} = -\frac{S'}{S}$$

Why there is a negative sign in the above expression?

$$m = \frac{h'}{h} = -\left(\frac{S' - f}{f}\right)$$

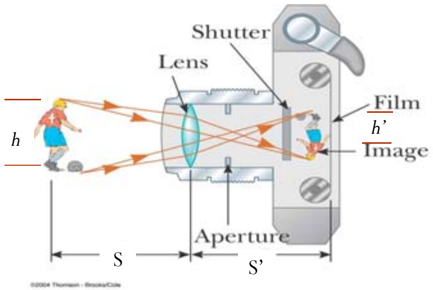
$$\frac{1}{f} = \frac{1}{S} + \frac{1}{S'}$$ **How?**

Example: 24.3

A lens has a focal length of +0.1 m. Find the image distance when the object distance is (a) 0.5 m; (b) 0.08 m.

Example: 24.4

A camera man lens has a focal length of +0.1 m. (a)if the camera is focused on a child 2 m from the lens, what is the distance from the lens to the film? (b) If the child has a height of 1 m, how tall is the image on the film?



Example: 24.5

A diverging lens has a focal length of -0.4 m. (a) Find the image location for an object placed 2m from the lens. (b) If there is a real image 1m from the lens, where is the object?

24.4 The Power of a lens; Aberration

The power of the lens (*P*) : is the reciprocal of the focal length

$$P = \frac{1}{f}$$

The unit of the power of the lens is m^{-1} or diopter
The power of two lenses placed next to each other are equivalent to a single lens with a foal length f satisfying

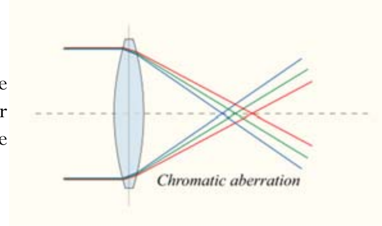
$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

Alternatively; with $P_1 = 1/f_1$ and $P_2 = 1/f_2$, the power of the system is $P = P_1 + P_2$

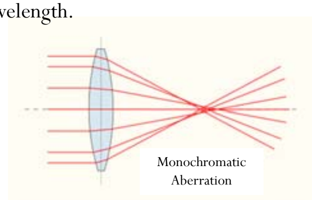
Aberration

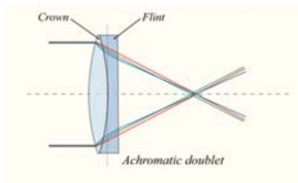
Any lens suffers from various kinds of aberration, which limit the sharpness of its image.
Since the refraction index of glass varies with wavelength of the light, the focal length also varies with the wavelength.

The Chromatic Aberration:
If an object illuminated with white light, if the image on a screen is in focus for one color component, it will be slightly our of focus for the others.

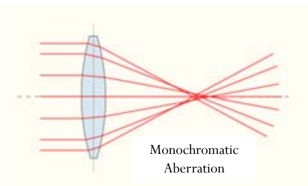


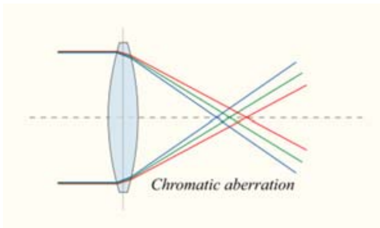
The Monochromatic Aberration:
Aberration occur even fro light of a single wavelength.



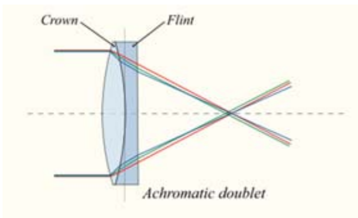


Aberration Correction

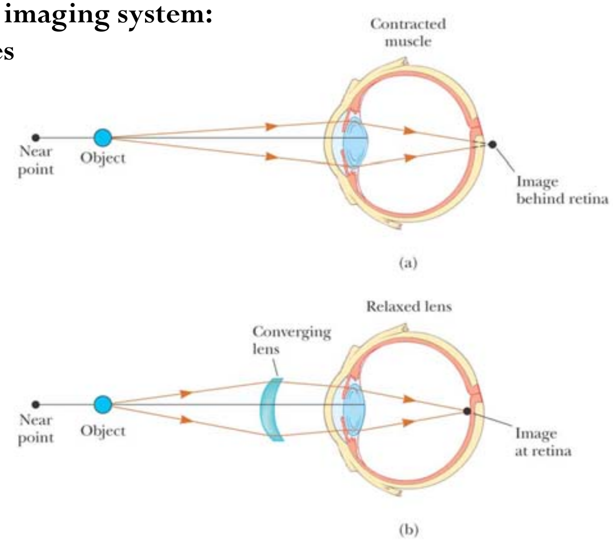


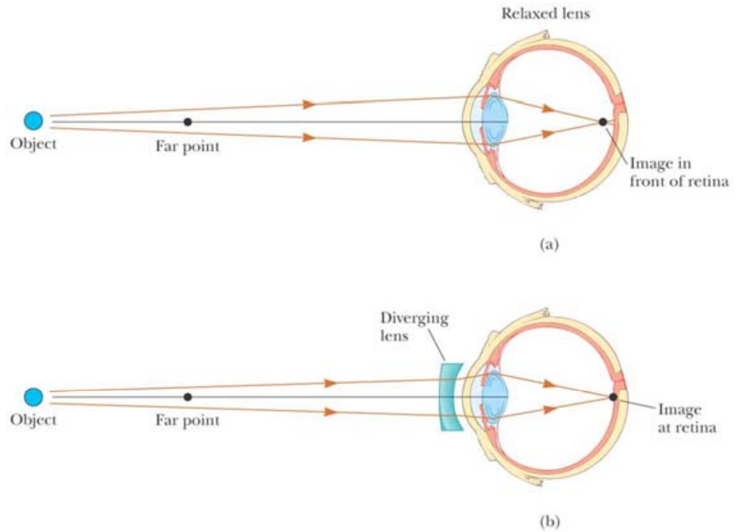


By adding a corrector lens we can reduce or cancel the aberration



Human imaging system: The Eyes




Relaxed lens
Object
Far point
Image in
front of retina
(a)
Diverging
lens
Object
Far point
Image
at retina
(b)