4.2 Lenses

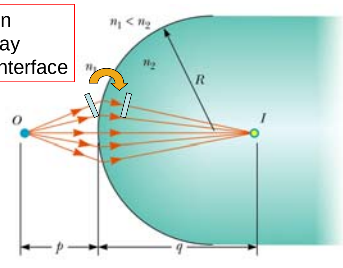
Images formed by refraction
Images formed by a thin lens

Image formed by refraction

- Light rays are deflected by refraction through media with different refractive indexes.
- An image is formed by refraction across flat or curved interfaces and by passage through lenses.

Image formed by refraction through a refracting surface.

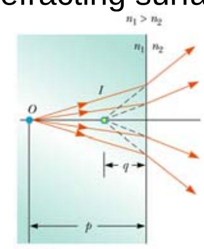
Rotation of the ray at the interface



Light is caused to Converge.

Real image formed by refraction.

Image formed by refraction through a refracting surface.

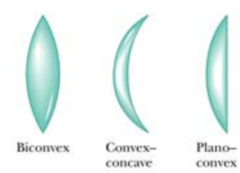


Light is caused to diverge in a different direction.

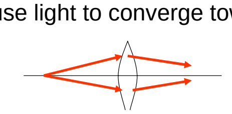
Virtual Image formed by refraction.

Why is the pencil bent?

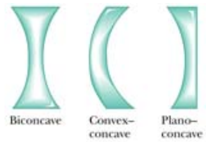
Converging Lenses



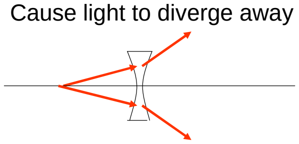
Fatter in the middle.
Cause light to converge toward the optic axis



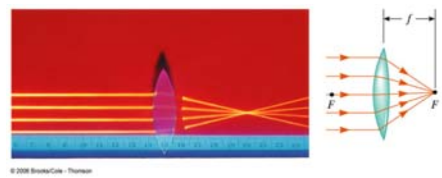
Diverging Lenses



Thinner in the middle
Cause light to diverge away from the optic axis



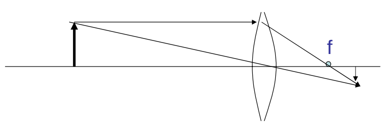
Parallel light though a converging lens is focused at the focal point.



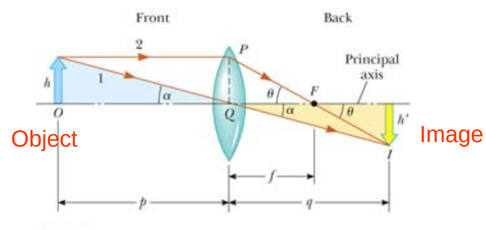
A real image is formed

Ray tracing for lenses

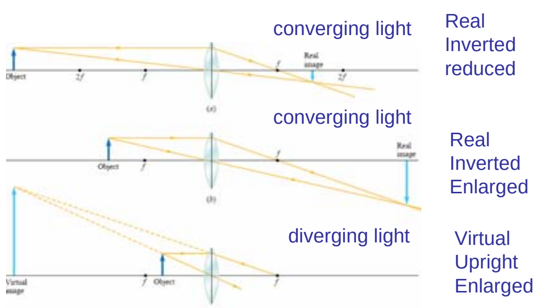
- A line parallel to the lens axis passes through the focal point
- A line through the center of the lens passes through undeflected.



Ray diagram for a converging lenses



Images formed by a converging lens



At the focal point the image changes from real to virtual

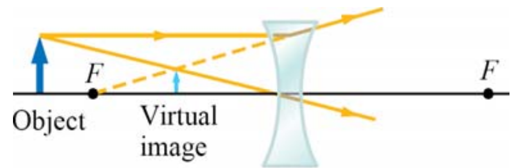
Question

How will an object viewed through a converging lens appear as the lens is brought closer to the object?

Parallel light though a diverging lens appears to go through the focal point.

A virtual image is formed.

Image formed by a diverging lens



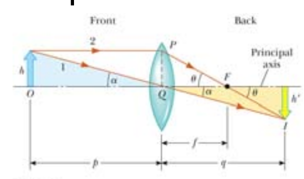
Virtual
Upright
Reduced

Question

How will the image of an object formed by a diverging lens change as the lens is brought closer to the object?

Thin lens equation.

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

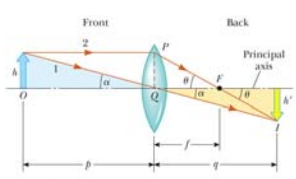


p and q are positive if light passes through

p is positive for real objects
f is positive for converging lenses
f is negative for diverging lenses
q is positive for real images
q is negative for virtual images.

Magnification

$$M=-\frac{h'}{h}=-\frac{q}{p}$$

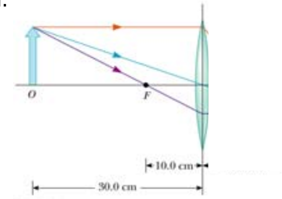


M positive- upright
M negative- inverted

for real image
  q is positive – image is inverted
for virtual image
  q is negative – image is upright

Example

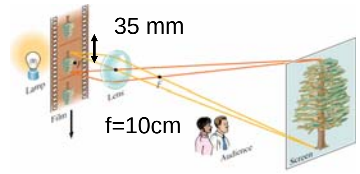
An object is placed 30 cm in front of a converging lens with focal length 10 cm. Find the object distance and magnification.



Example

An object is placed 30 cm in front of a diverging lens with a focal length of -10 cm. Find the image distance and magnification

Projector lens



Suppose you want to project the image of a transparency 35 mm high on to a screen that is 1.5 m high using a lens with a focal length of 10 cm. Where would you position the film? How far from the lens would you place the screen?

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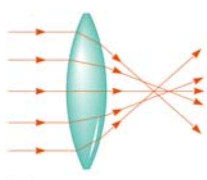
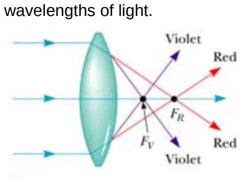
Lens aberrations

- Aberrations prevent the formation of a perfect image and limit the magnification of a lens or mirror.
  - Spherical Aberration- due to deviation of spherical surface from the ideal parabolic shape.
  - Chromatic aberration – due to the difference in refractive index and thus the focal length for different wavelengths of light.



Spherical aberration



Chromatic aberration