4.3 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.

Refraction of Light

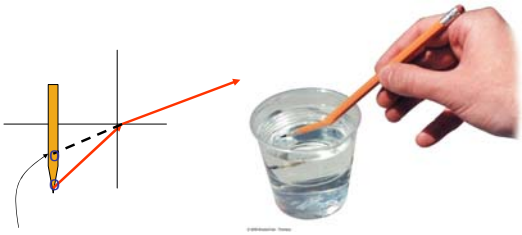
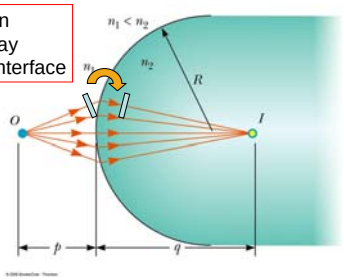


Image of the tip

Real Image formed by refraction

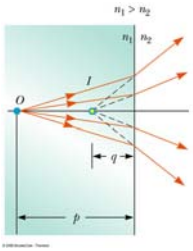
Rotation of the ray at the interface



Light is caused to Converge.

Real image formed by refraction.

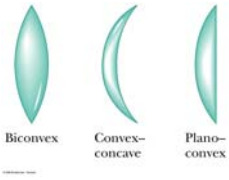
Virtual Image formed by refraction



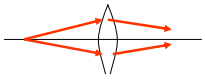
Light is caused to diverge in a different direction.

Virtual Image formed by refraction.

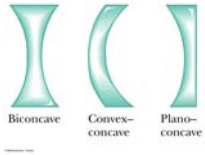
Converging Lenses



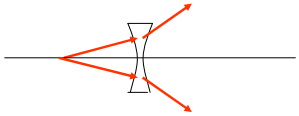
Fatter in the middle.
Cause light to converge toward the optic axis



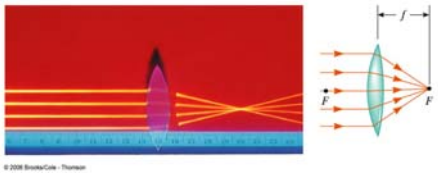
Diverging Lenses



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



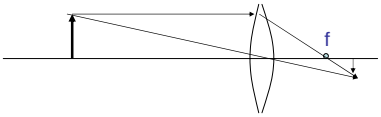
Converging lens - Parallel light is focused at the focal point.



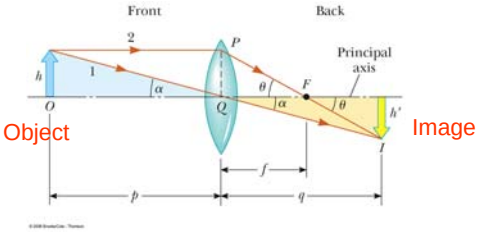
A real image is formed

Ray tracing for lenses

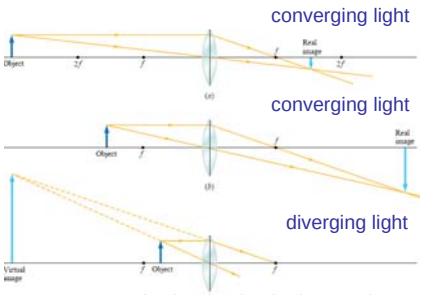
- A line parallel to the lens axis passes through the focal point
- A line through the center of the lens passes through undeflected.



Ray diagram for a converging lenses



Images formed by a converging lens



converging light — Real Inverted reduced

converging light — Real Inverted Enlarged

diverging light — Virtual Upright Enlarged

At the focal point the image changes from real to virtual

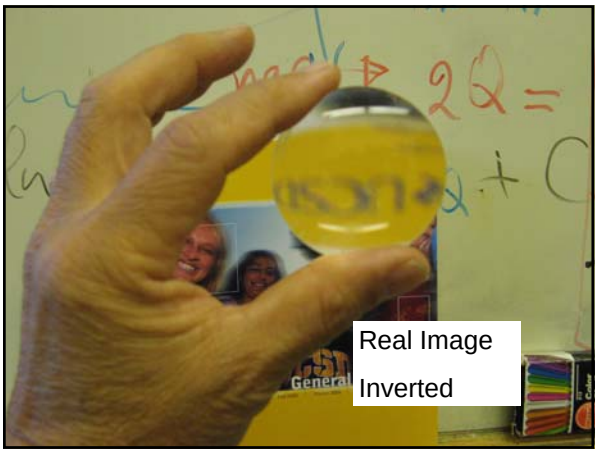
Simulation of image formation by a lens

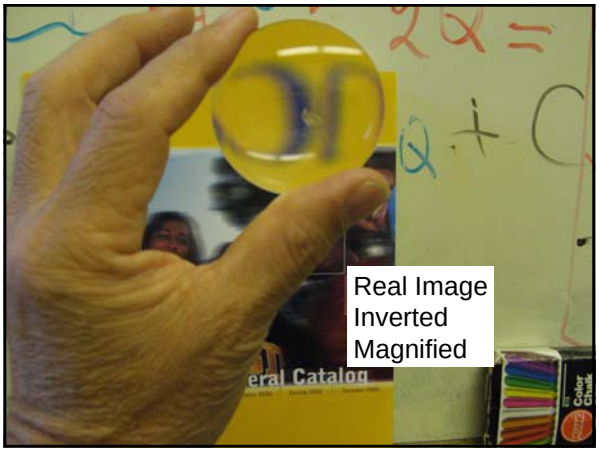
http://qbx6.ltu.edu/s_schneider/physlets/main/opticsbench.shtml

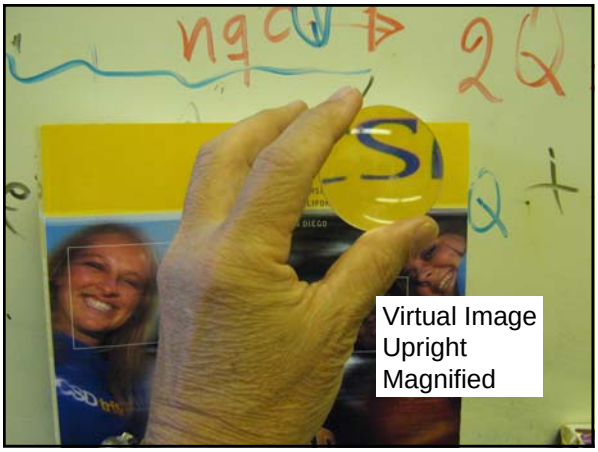
PHYSLETS were developed at Davidson University by Wolfgang Christian.

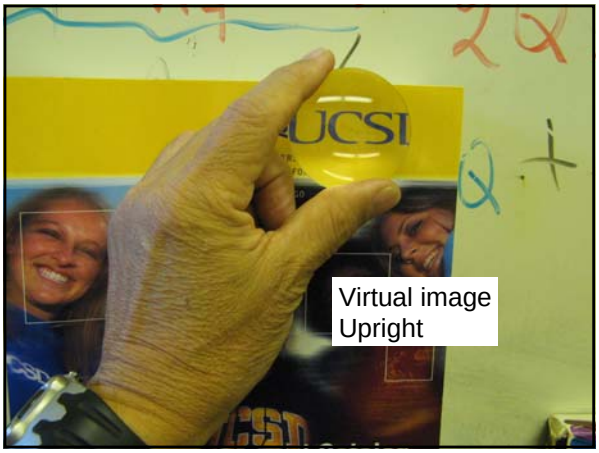
Question

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





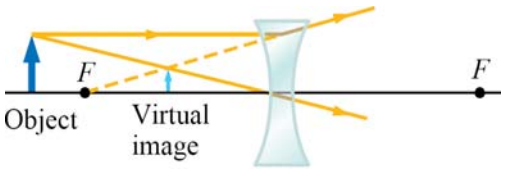




Parallel light though a diverging lens appears to go through the focal point.

A virtual image is formed.

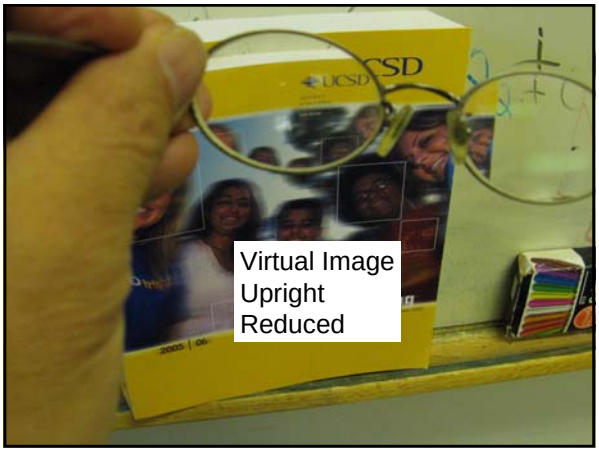
Image formed by a diverging lens

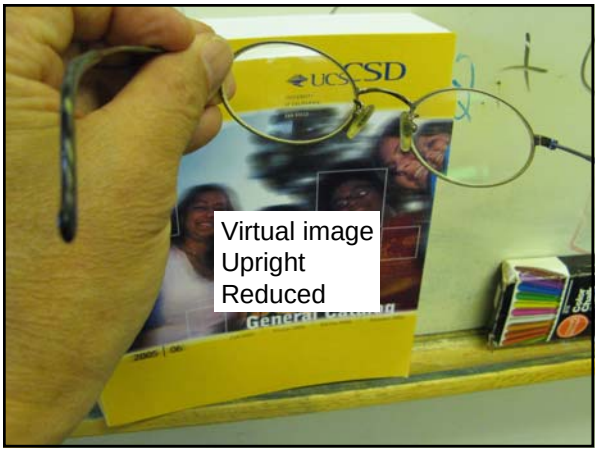


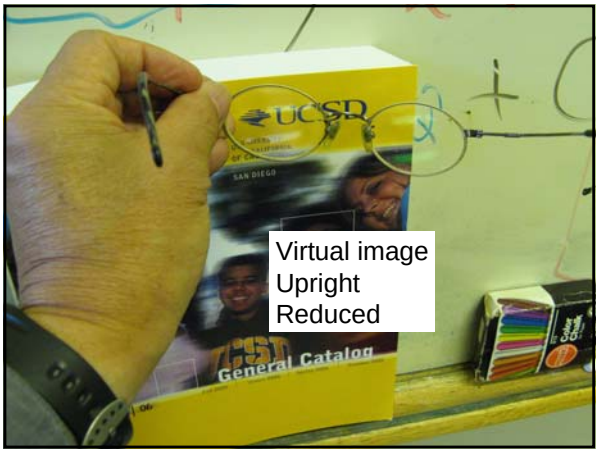
Virtual
Upright
Reduced

Question

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

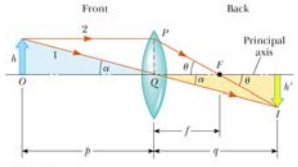






Thin lens equation.

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

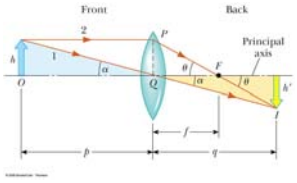


p and q are positive if light passes through

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

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

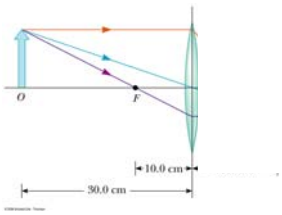


M positive- upright
M negative- inverted

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

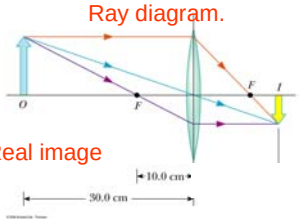
An object is placed 30 cm in front of a converging lens with focal length 10 cm. Find the object distance and magnification.

Ray diagram.

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

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

$$q=\frac{fp}{p-f}=\frac{(10)(30)}{30-10}=15\text{cm}$$



Real image

$$M=-\frac{q}{p}=-\frac{15}{30}=-0.5$$

Inverted
Reduced

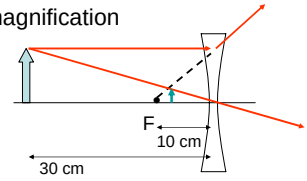
Example

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

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

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

$$q=\frac{fp}{p-f}=\frac{(-10)(30)}{30-(-10)}=-7.5\text{cm}$$



Virtual image

$$M=-\frac{q}{p}=-\frac{-7.5}{30}=0.25$$

Upright image
reduced