

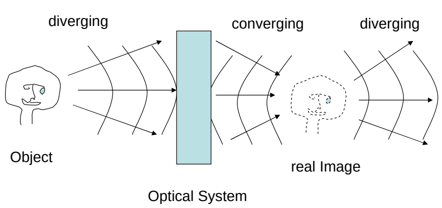

4.1 Images formed by Mirrors and Lenses

- Images
- Image formation by mirrors
- Images formed by lenses

Object-Image

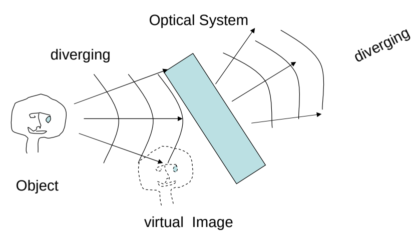
- A physical object is usually observed by reflected light that diverges from the object.
- An optical system (mirrors or lenses) can produce an image of the object by redirecting the light.
  - Real Image
  - Virtual Image

Real Image



Light passes through the real image
Film at the position of the real image is exposed.

Virtual Image



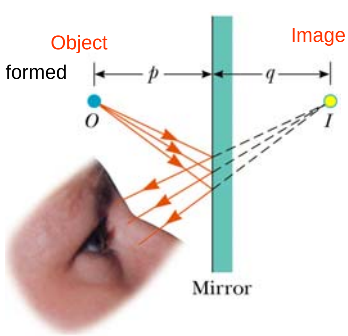
Light appears to come from the virtual image but does not pass through the virtual image

Film at the position of the virtual image is not exposed.

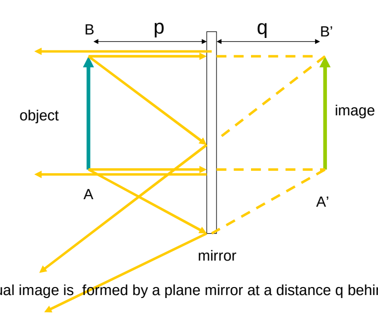
Image formed by a plane mirror.

The virtual image is formed directly behind the mirror.

Light does not pass through the image



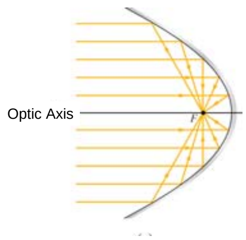
Each point on the image can be determined by tracing 2 rays from the object.



A virtual image is formed by a plane mirror at a distance q behind the mirror.

$q = -p$

Parabolic Mirrors



Parallel rays reflected by a parabolic mirror are focused at a point, called the Focal Point located on the optic axis.

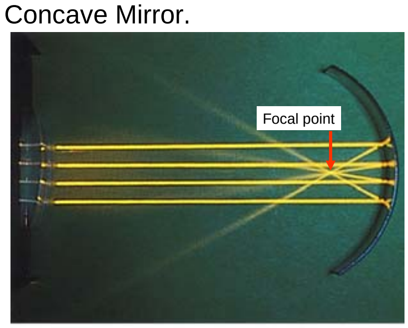
Parabolic Reflector

Parabolic mirrors can be used to focus incoming parallel rays to a small area or to direct rays diverging from a small area into parallel rays.

Spherical mirrors

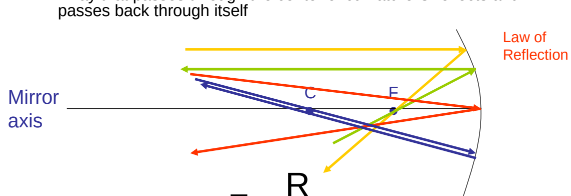
- Spherical mirrors are much easier to fabricate than parabolic mirrors
- A spherical mirror is an approximation of a parabolic mirror for small curvatures. (i.e. for paraxial rays –close to parallel to the optic axis.
- Spherical mirrors can be convex or concave

Parallel beams focus at the focal point of a Concave Mirror.



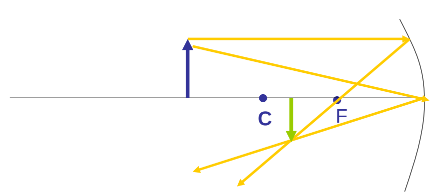
Ray tracing with a concave spherical mirrors

- A ray parallel to the mirror axis reflects through the focal point, **F** which is at a point half the radius distance from the mirror along the optic axis.
- A ray passing through the focal point reflects parallel to the mirror axis
- A ray striking the center of the mirror reflects symmetrically around the mirror axis
- A ray that passes through the center of curvature **C** reflects and passes back through itself



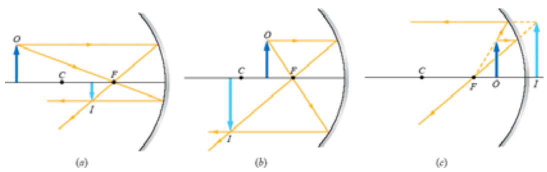
$$F = \frac{R}{2}$$

The position of the image can be determined from two rays from the object.



When object distance > C
The image is real, inverted, reduced

A concave mirror can form real and virtual images



O > C	C > O > F	F > O
Real Inverted Reduced	Real Inverted Enlarged	Virtual Upright Enlarged

Simulation of image formation by a mirror

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

PHYSLETS were developed at Davidson University by Wolfgang Christian.

Question

What image of yourself do you see when you move toward a concave mirror?

Convex Mirror

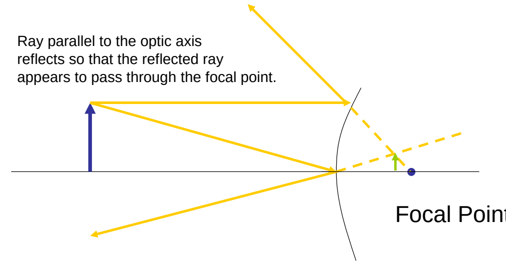
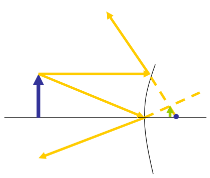
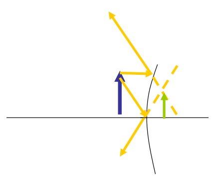


Image is virtual, upright, reduced

A Convex Mirror always forms virtual images



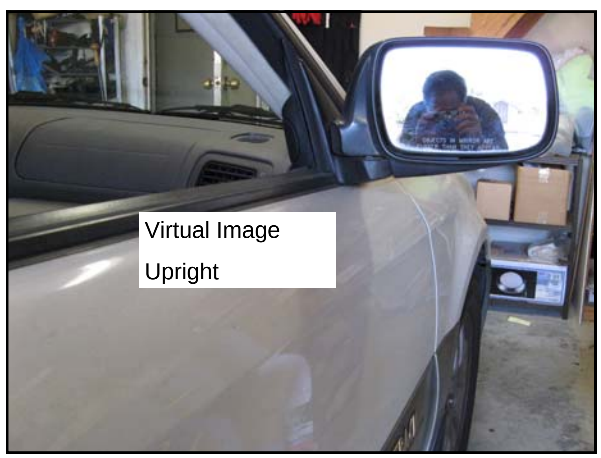
virtual,
upright,
reduced



virtual,
upright,
reduced

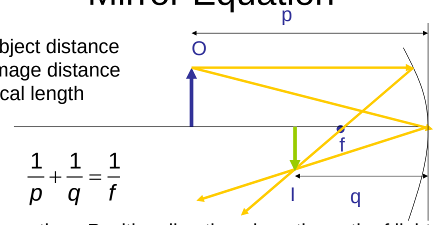
Question

Describe how your image would appear as you approach a convex mirror?



Mirror Equation

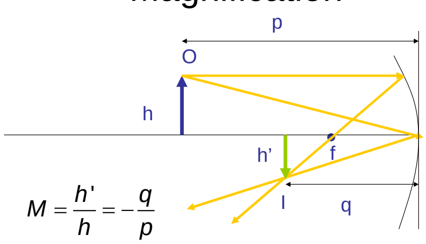
p – object distance
q – image distance
f - focal length



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

Sign convention. Positive direction along the path of light
p is positive for real objects.
q is positive if the light goes through the image – real image
q is negative if light does not go through image – virtual image
f is positive if the light from infinity goes through the focal point.
f is positive for concave mirrors,
f is negative for convex mirrors

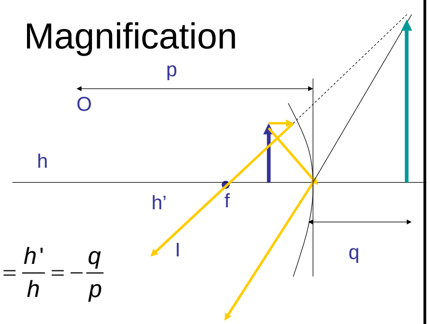
Magnification



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

q –positive – image is real
M is negative - the image is inverted.

Magnification

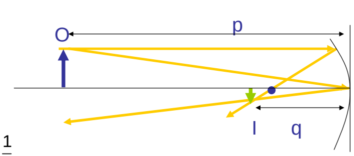


$$M=\frac{h'}{h}=-\frac{q}{p}$$

q is negative – the image is virtual
M is positive – the image is upright.

Question

A boy stands 2.0 m in front of a concave mirror with a focal length of 0.50 m. Find the position of the image. Find the magnification. Is the image real or virtual? Is the image inverted or erect?



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

$$\frac{1}{q}=\frac{1}{f}-\frac{1}{p} \rightarrow q=\frac{fp}{p-f} = \frac{0.5(2.0)}{2.0-0.5}=0.67m$$ Real image

$$m=-\frac{q}{p} = -\frac{0.67}{2.0}=-0.33$$ inverted

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

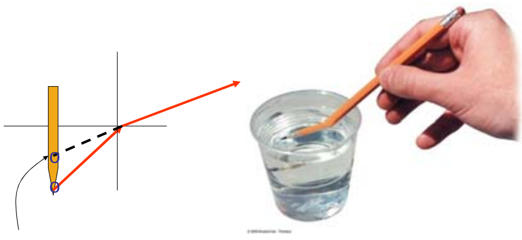
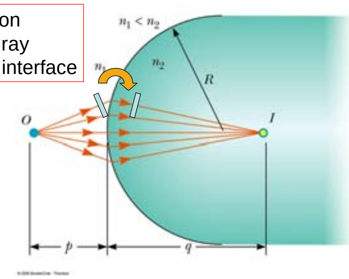


Image formed by refraction through a refracting surface.

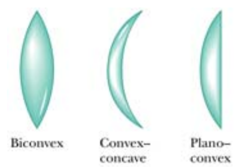
Rotation of the ray at the interface



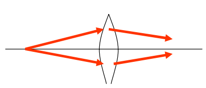
Light is caused to Converge.

Real image formed by refraction.

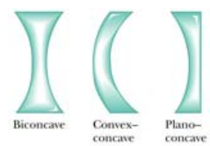
Converging Lenses



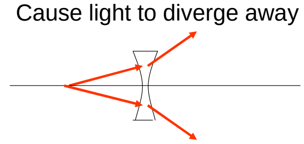
Fatter in the middle.
Cause light to converge toward the optic axis



Diverging Lenses



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

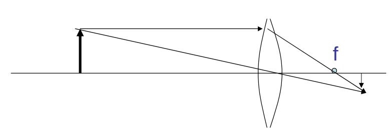


Parallel light though a converging lens is focused at the focal point.

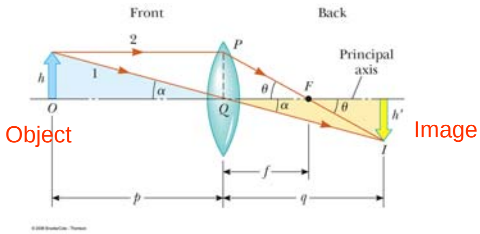
A real image is formed

Ray tracing for lenses

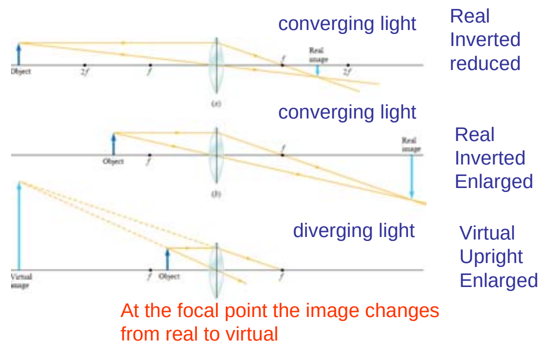
- A line parallel to the lens axis passes through the focal point
- A line through the center of the lens passes through undeflected.



Ray diagram for a converging lenses

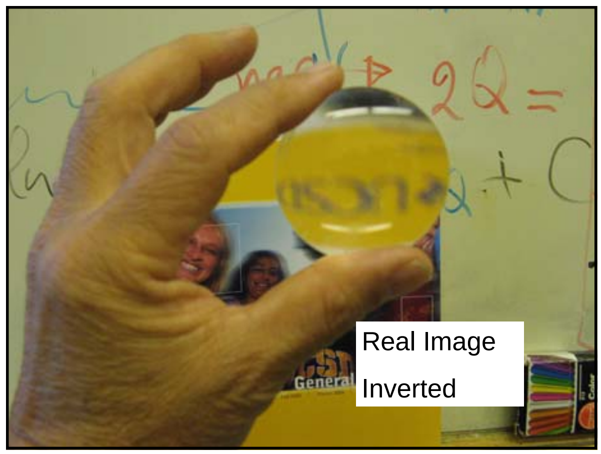


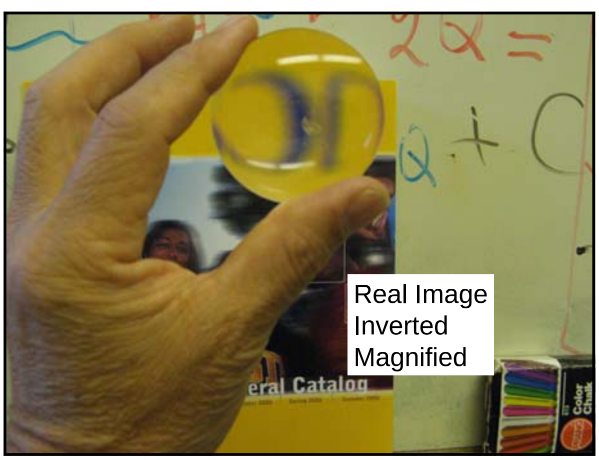
A converging lens can form real and virtual images

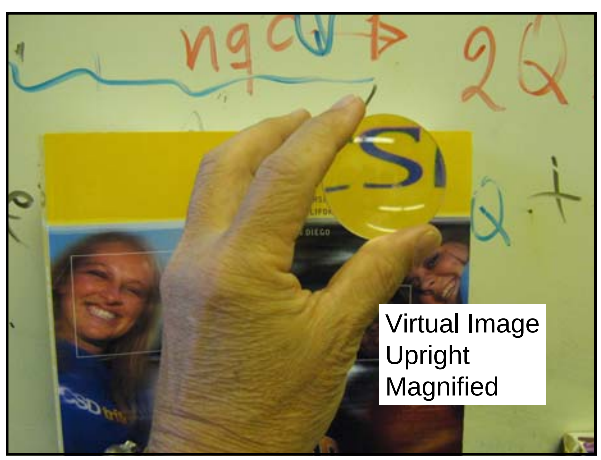


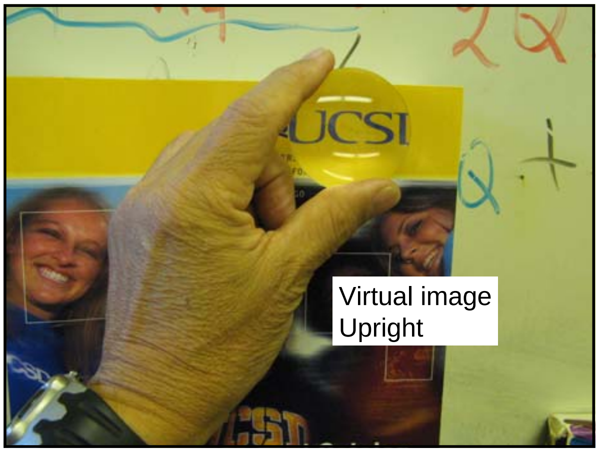
Question

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

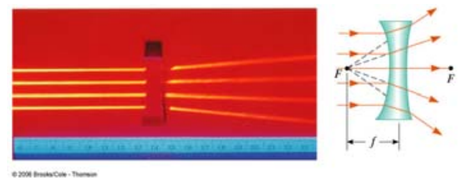






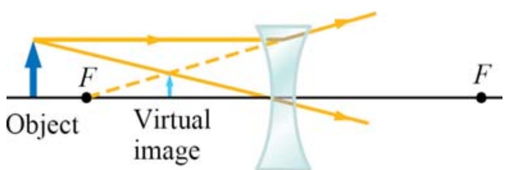


Parallel light though a diverging lens appears to go through the focal point.



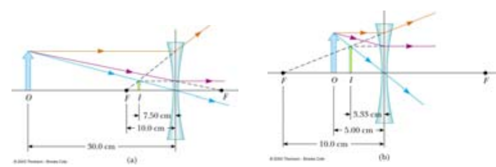
A virtual image is formed.

Image formed by a Diverging lens



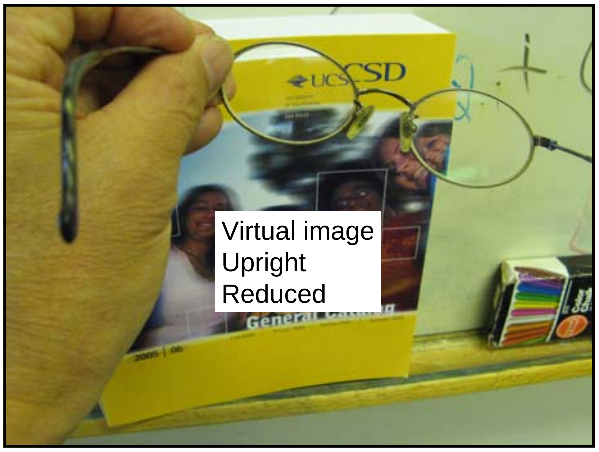
Virtual
Upright
Reduced

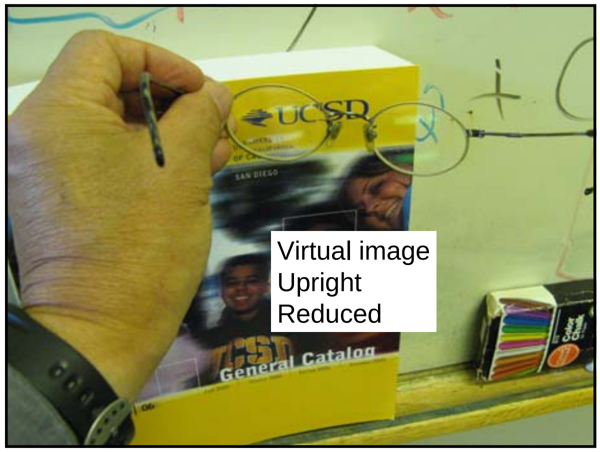
A Diverging lens always forms a virtual image



Question

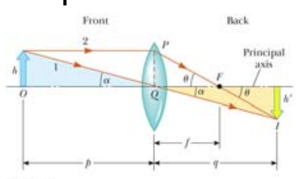
How will the image of an object formed by a diverging lens change as the lens is brought closer to the object?





Thin lens equation.

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

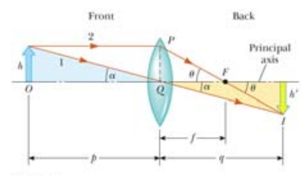


p and q are positive along the path of light

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

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

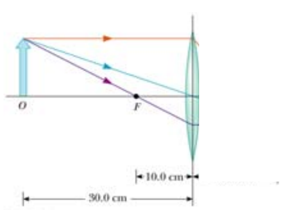


M positive- upright
M negative- inverted

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

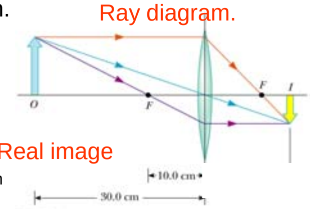
An object is placed 30 cm in front of a converging lens with focal length 10 cm. Find the object distance and magnification.

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

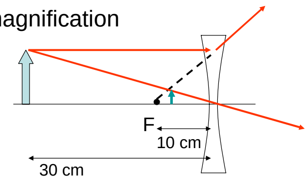
Example

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

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

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

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



Virtual image

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

Upright image
reduced