Geometric optics

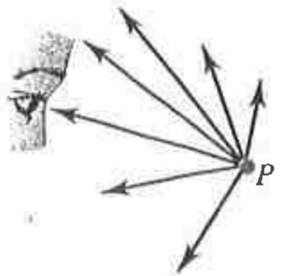
PHY117 HS2023

Week 10, Lecture 1

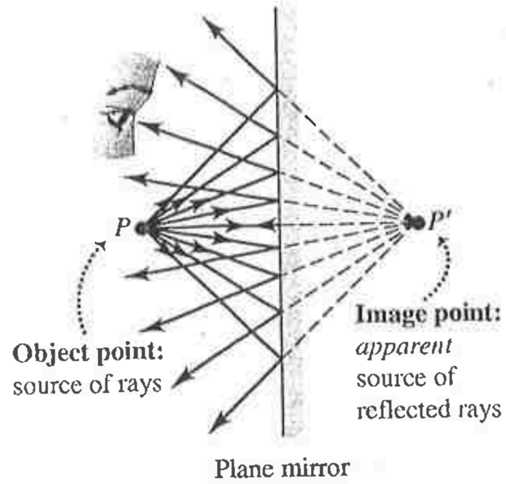
Nov. 21st, 2023

Prof. Ben Kilminster

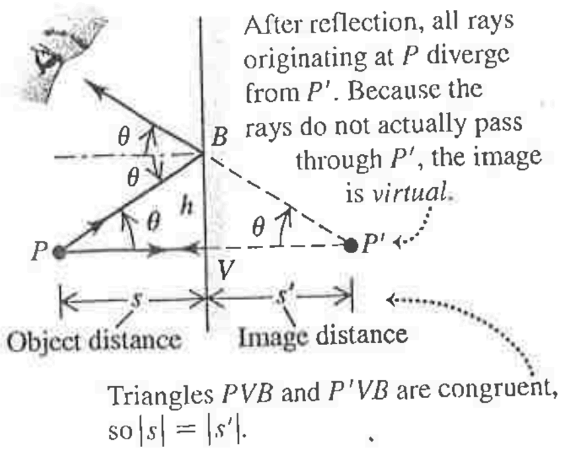
34.1 Light rays radiate from a point object P in all directions. For an observer to see this object directly, there must be no obstruction between the object and the observer's eyes.



34.2 Light rays from the object at point P are reflected from a plane mirror. The reflected rays entering the eye look as though they had come from image point P'.

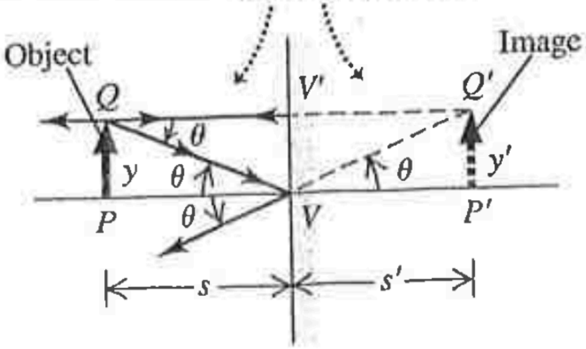


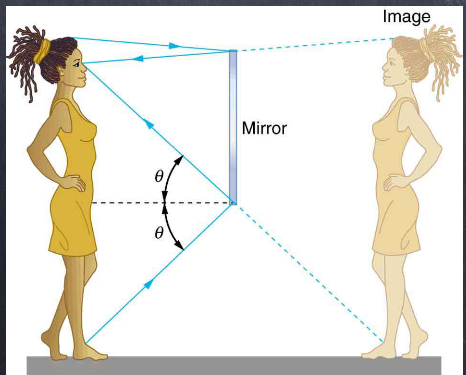
34.4 Construction for determining the location of the image formed by a plane mirror. The image point P' is as far behind the mirror as the object point P is in front of it.

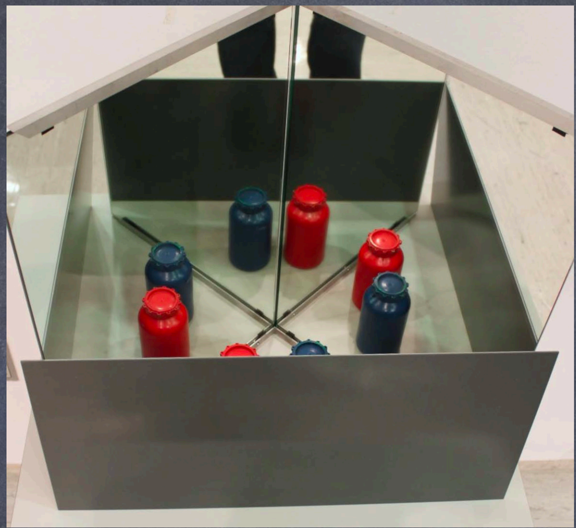


34.6 Construction for determining the height of an image formed by reflection at a plane reflecting surface.

For a plane mirror, PQV and $P'Q'V$ are congruent, so $y = y'$ and the object and image are the same size (the lateral magnification is 1).

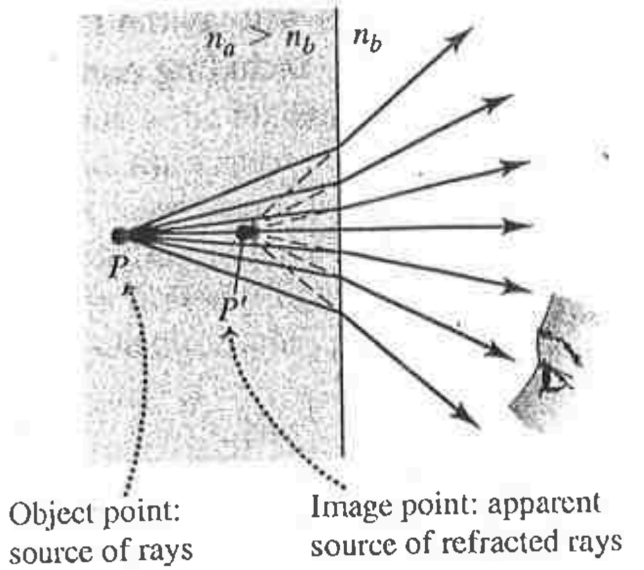


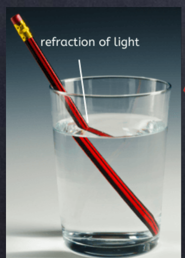


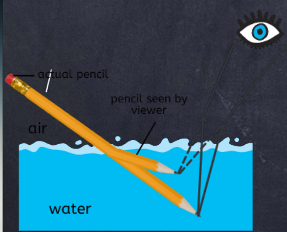


34.3 Light rays from the object at point P are refracted at the plane interface. The refracted rays entering the eye look as though they had come from image point P'.

When $n_a > n_b$, P' is closer to the surface than P; for $n_a < n_b$, the reverse is true.

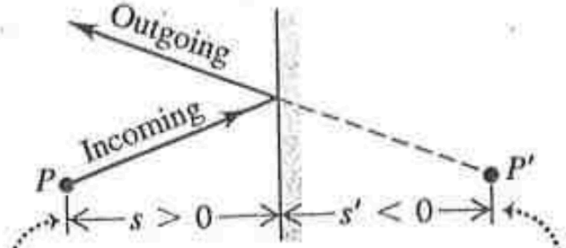






34.5 For both of these situations, the object distance s is positive (rule 1) and the image distance s' is negative (rule 2).

(a) Plane mirror

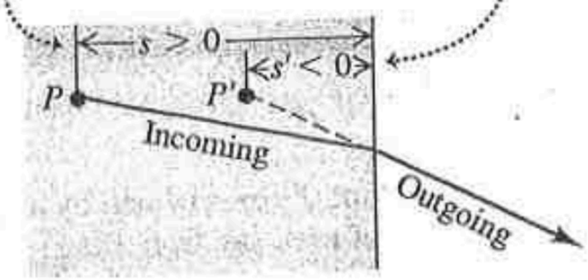


In both of these specific cases:

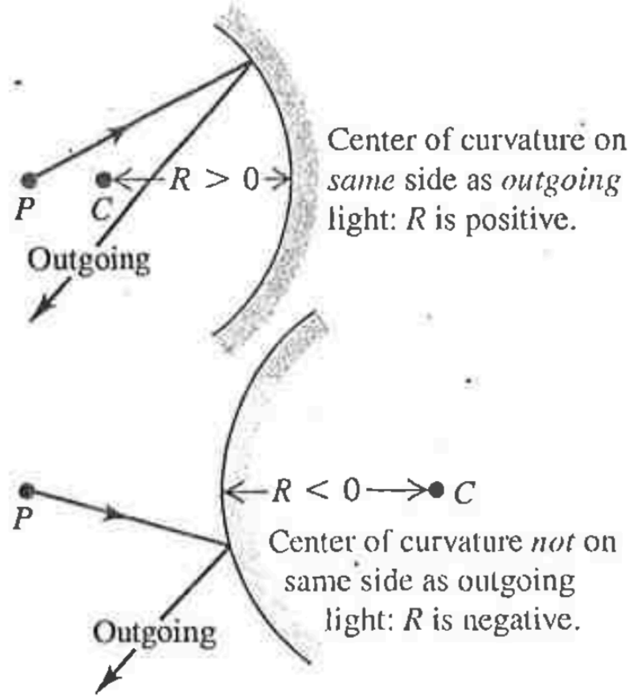
Object distance s **is** *positive* because the *object is on the same side as the incoming light.*

Image distance s' **is** *negative* because the *image is NOT on the same side as the outgoing light.*

(b) Plane refracting interface

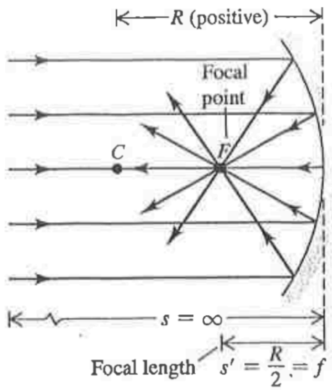


34.11 The sign rule for the radius of a spherical mirror.

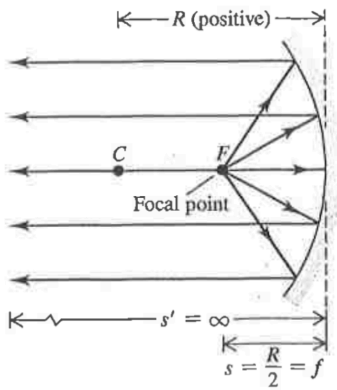


34.13 The focal point and focal length of a concave mirror.

(a) All parallel rays incident on a spherical mirror reflect through the focal point.

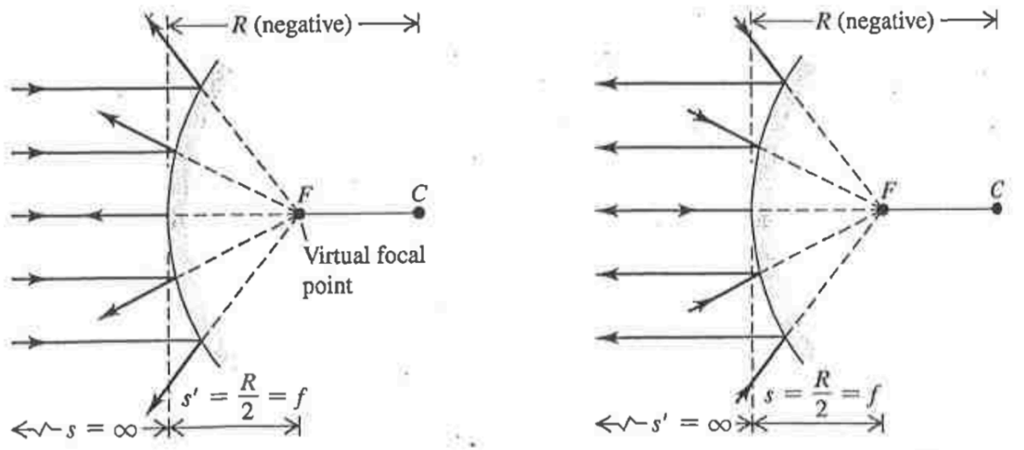


(b) Rays diverging from the focal point reflect to form parallel outgoing rays.



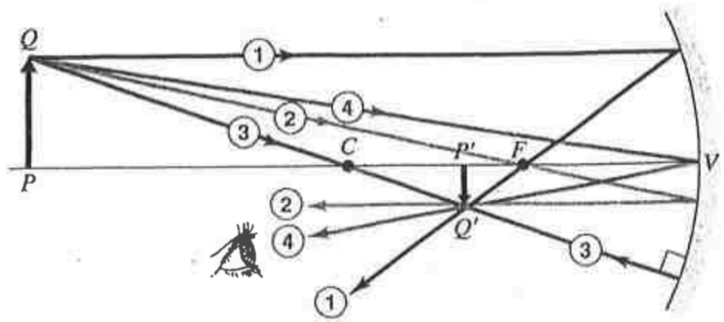
(a) Paraxial rays incident on a convex spherical mirror diverge from a virtual focal point.

(b) Rays aimed at the virtual focal point are parallel to the axis after reflection.



34.19 The graphical method of locating an image formed by a spherical mirror. The colors of the rays are for identification only; they do not refer to specific colors of light.

(a) Principal rays for concave mirror



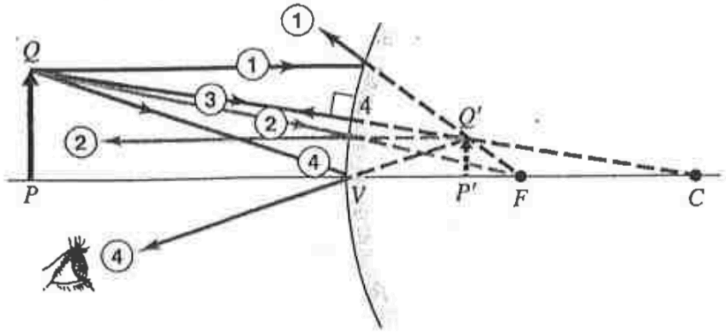
(1) Ray parallel to axis reflects through focal point.

(2) Ray through focal point reflects parallel to axis.

(3) Ray through center of curvature intersects the surface normally and reflects along its original path.

(4) Ray to vertex reflects symmetrically around optic axis.

(b) Principal rays for convex mirror



(1) Reflected parallel ray appears to come from focal point.

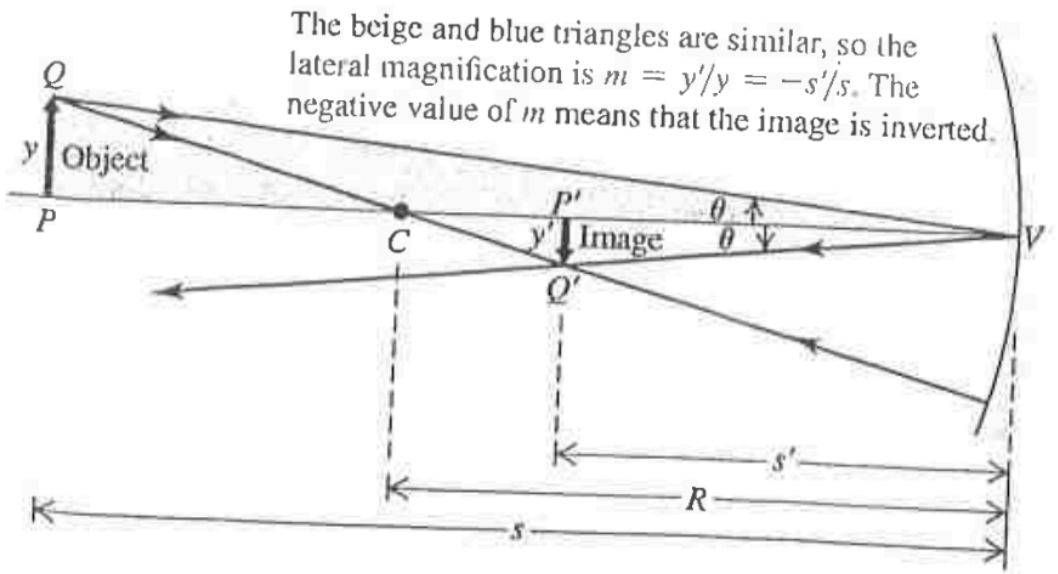
(2) Ray toward focal point reflects parallel to axis.

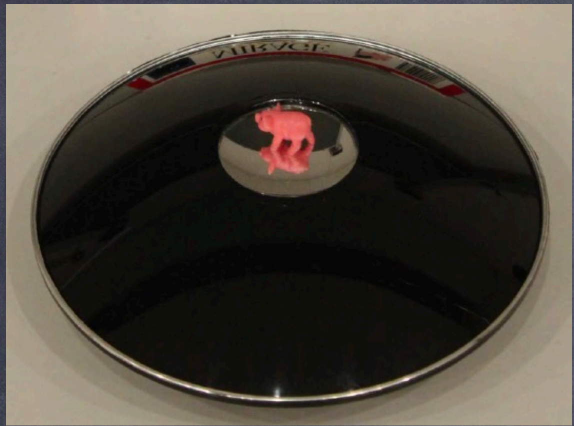
(3) As with concave mirror: Ray radial to center of curvature intersects the surface normally and reflects along its original path.

(4) As with concave mirror: Ray to vertex reflects symmetrically around optic axis.

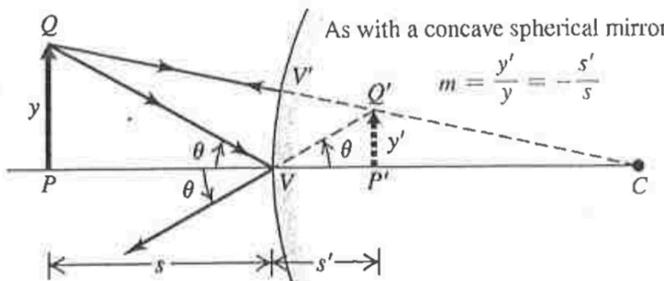
s	+	if the object is in front of the mirror (real object)
	−	if the object is behind the mirror (virtual object)*
s'	+	if the image is in front of the mirror (real image)
	−	if the image is behind the mirror (virtual image)
r,f	+	if the center of curvature is in front of the mirror (concave mirror)
	−	if the center of curvature is behind the mirror (convex mirror)

34.14 Construction for determining the position, orientation, and height of an image formed by a concave spherical mirror.





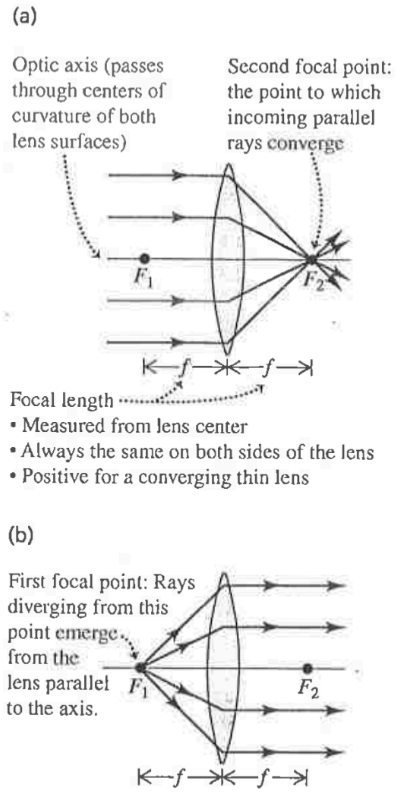
(b) Construction for finding the magnification of an image formed by a convex mirror



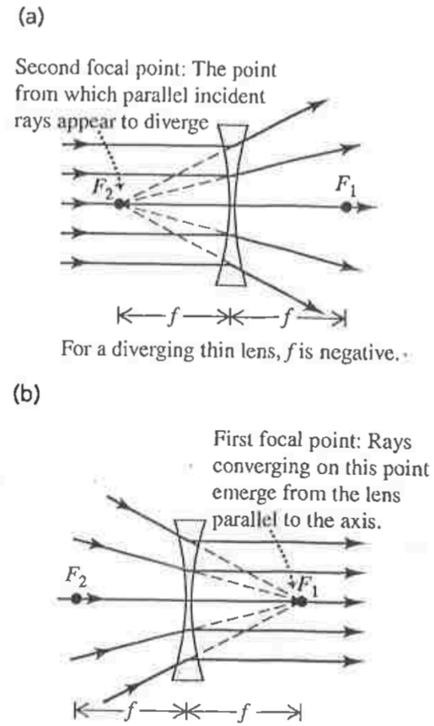
As with a concave spherical mirror,

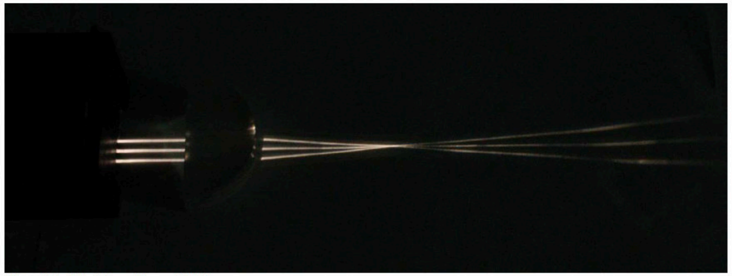
$$m = \frac{y'}{y} = -\frac{s'}{s}$$

34.28 F_1 and F_2 are the first and second focal points of a converging thin lens. The numerical value of f is positive.

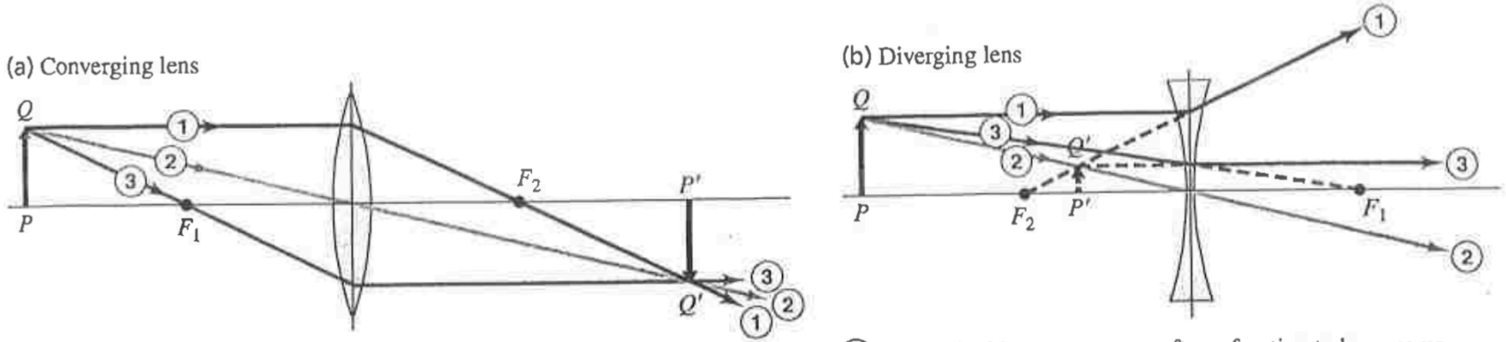


34.31 F_2 and F_1 are the second and first focal points of a diverging thin lens, respectively. The numerical value of f is negative.




Paraxiale Strahlen; Gauss Optik

34.36 The graphical method of locating an image formed by a thin lens. The colors of the rays are for identification only; they do not refer to specific colors of light. (Compare Fig. 34.19 for spherical mirrors.)



(a) Converging lens

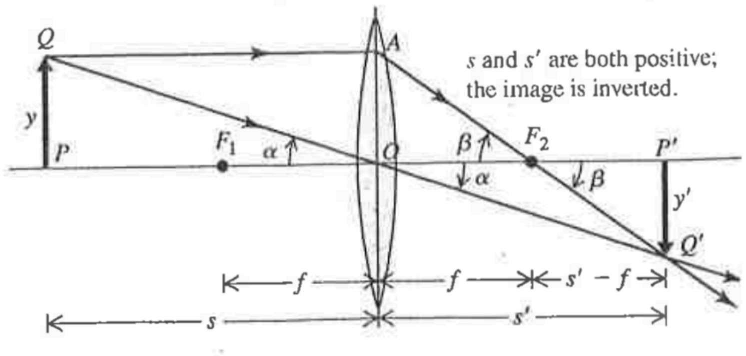
① Parallel incident ray refracts to pass through second focal point F_2.
② Ray through center of lens does not deviate appreciably.
③ Ray through the first focal point F_1 emerges parallel to the axis.

(b) Diverging lens

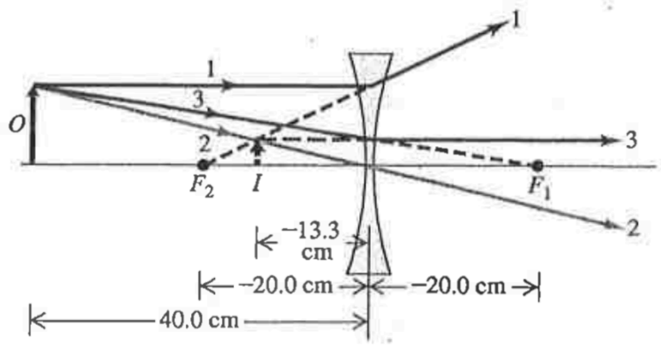
① Parallel incident ray appears after refraction to have come from the second focal point F_2.
② Ray through center of lens does not deviate appreciably.
③ Ray aimed at the first focal point F_1 emerges parallel to the axis.

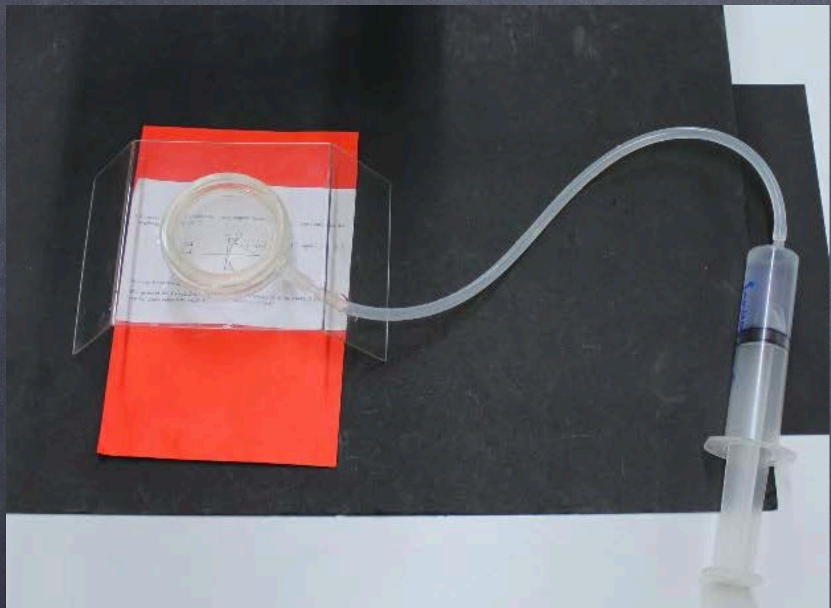
s	+	(real object) for objects in front of the surface (incident side)
	−	(virtual object) for objects in back of the surface (transmission side)
s'	+	(real image) for images in back of the surface (transmission side)
	−	(virtual image) for images in front of the surface (incident side)
r, f	+	if the center of curvature is on the transmission side
	−	if the center of curvature is on the incident side

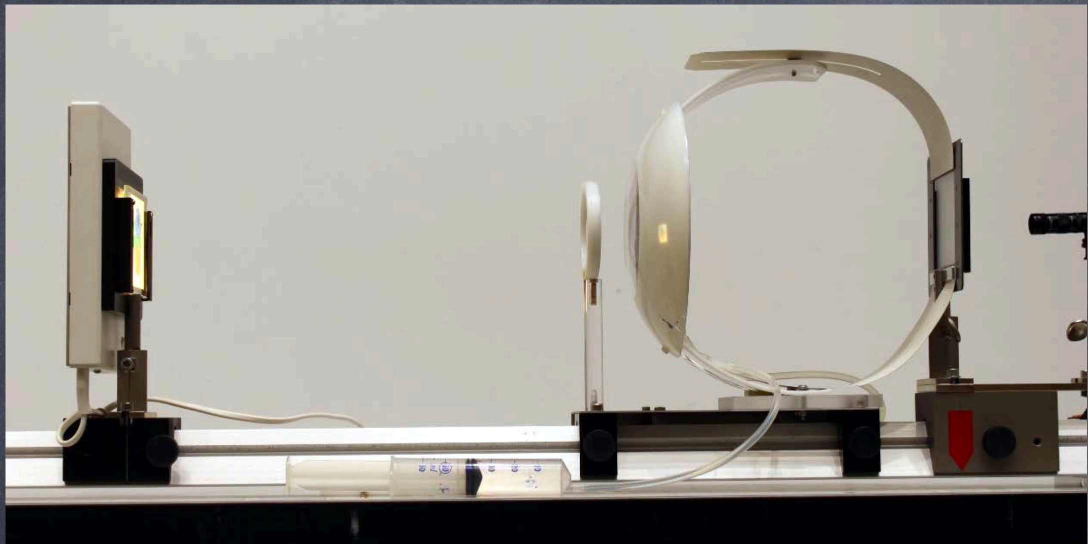
34.29 Construction used to find image position for a thin lens. To emphasize that the lens is assumed to be very thin, the ray QAQ' is shown as bent at the midplane of the lens rather than at the two surfaces and ray QOQ' is shown as a straight line.

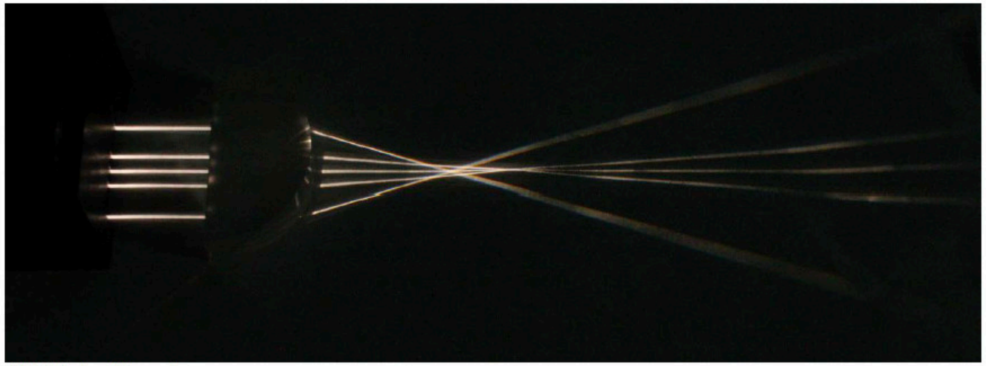


34.38 Principal-ray diagram for an image formed by a thin diverging lens.



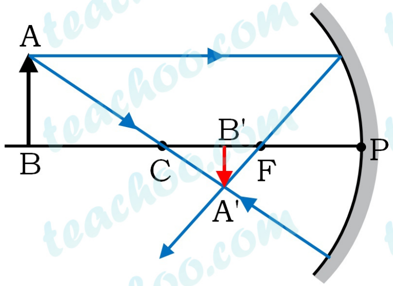


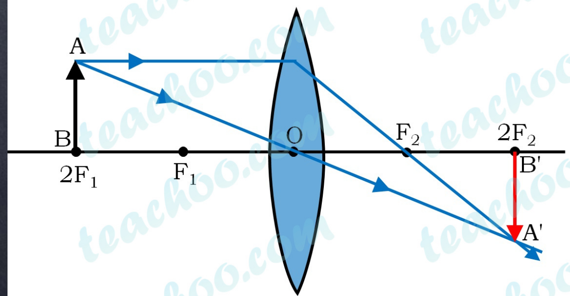



Sphärische Aberration

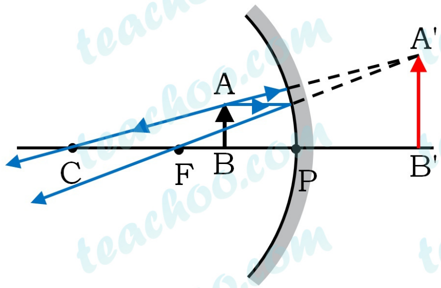
Real Image Vs Virtual Image

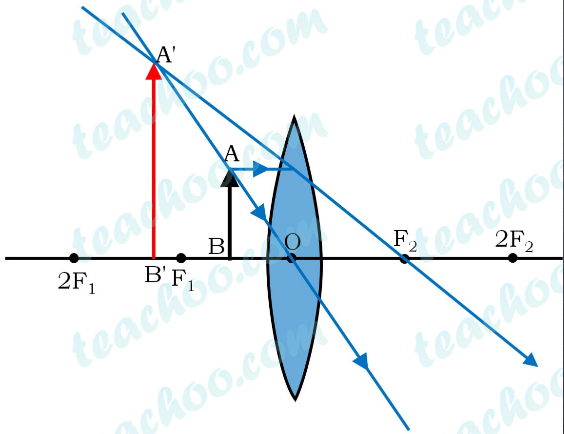
Real Image

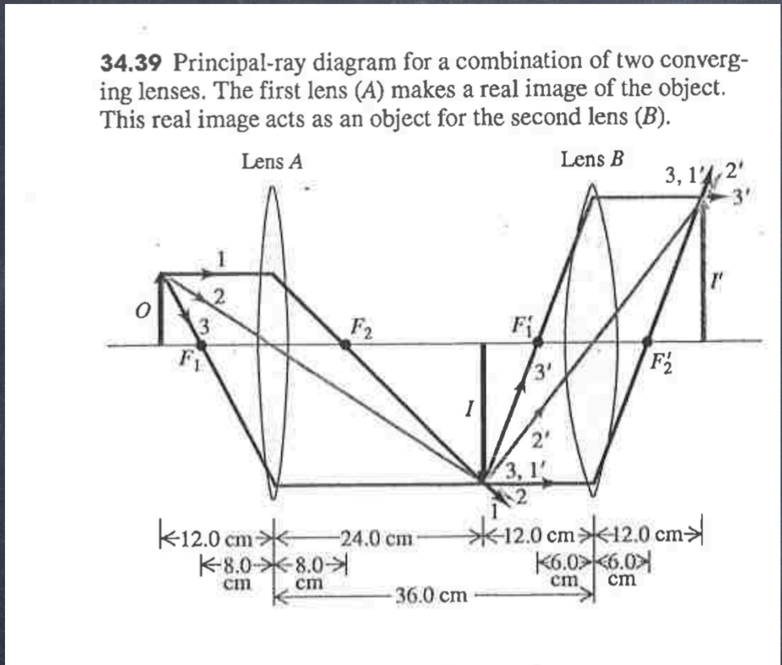


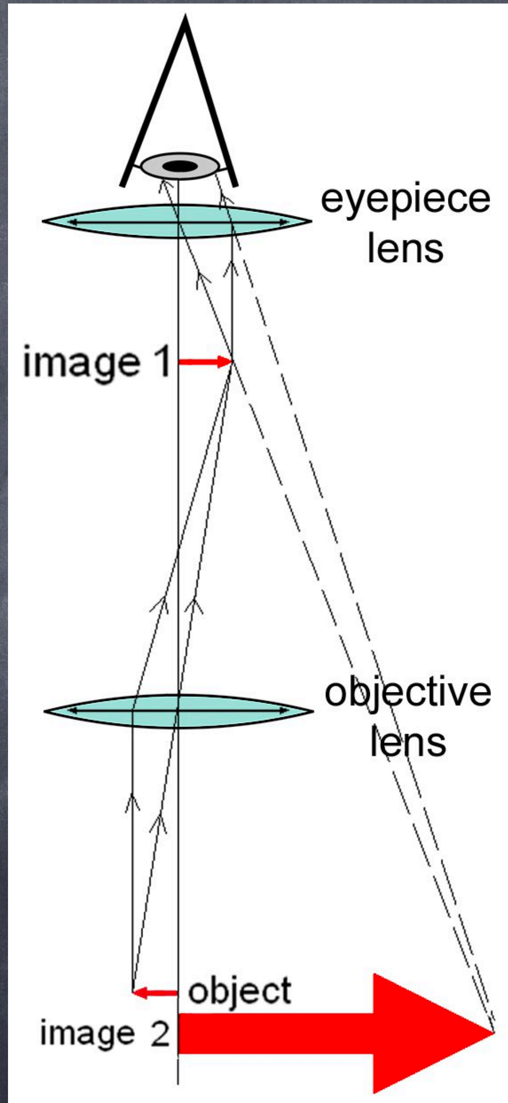


Virtual Image

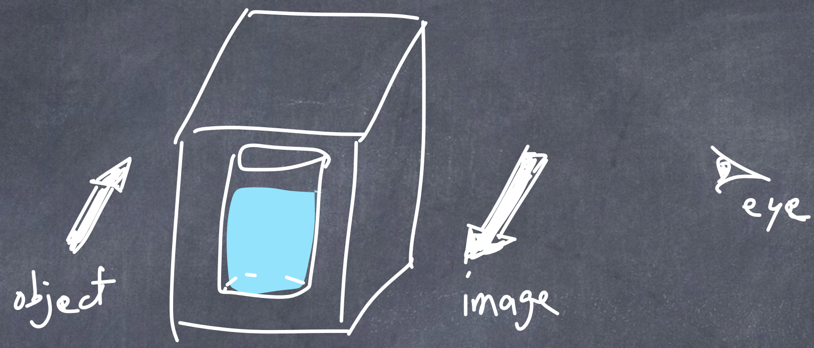





34.39 Principal-ray diagram for a combination of two converging lenses. The first lens (A) makes a real image of the object. This real image acts as an object for the second lens (B).
Lens A
Lens B
O
I
I'
F1
F2
F1'
F2'
12.0 cm
24.0 cm
12.0 cm
12.0 cm
8.0 cm
8.0 cm
6.0 cm
6.0 cm
36.0 cm


eyepiece lens
image 1
objective lens
object
image 2

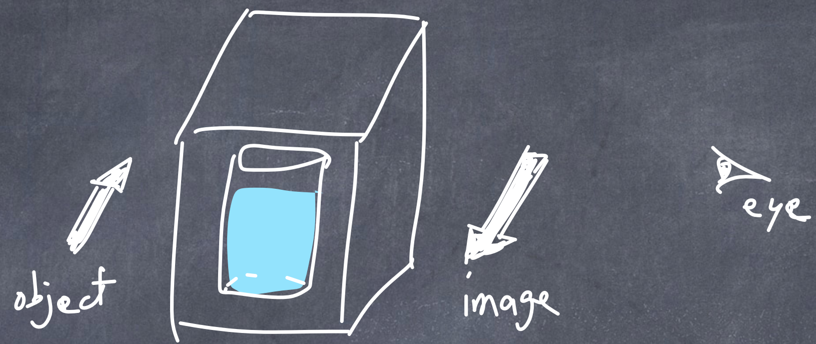
water glass



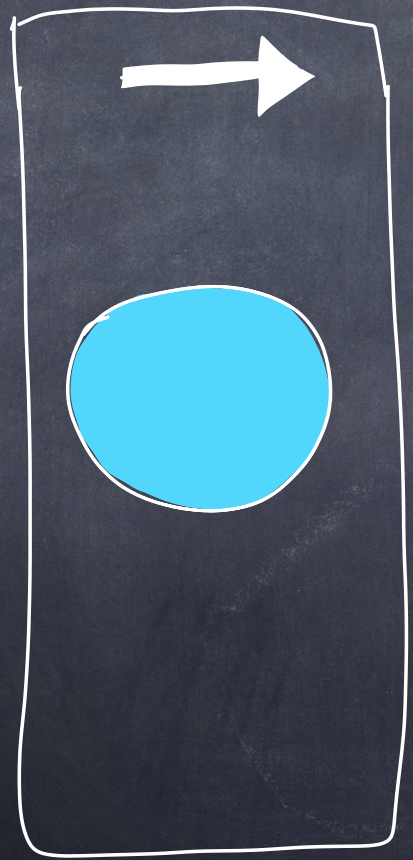
How?

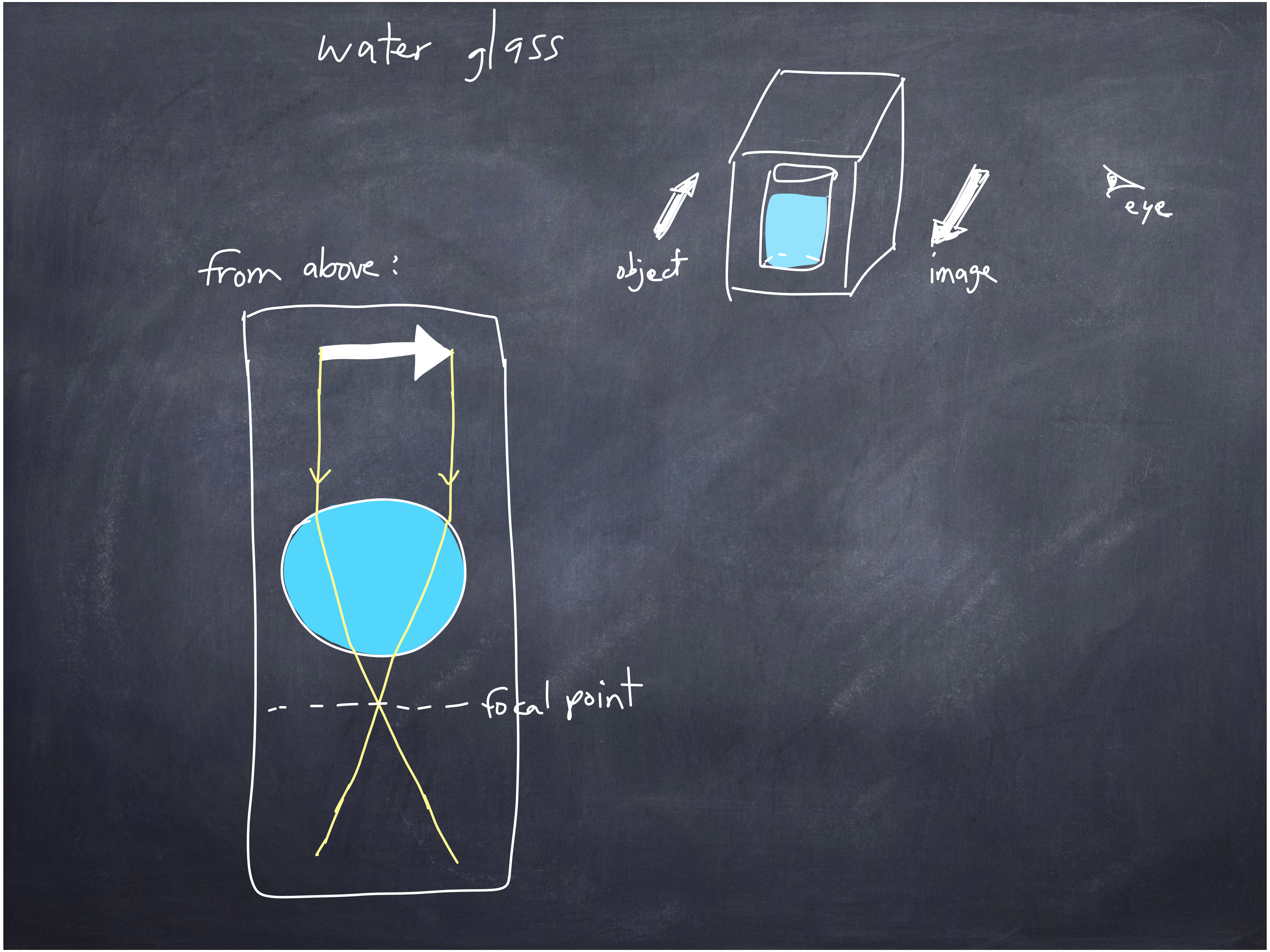
water glass

How?



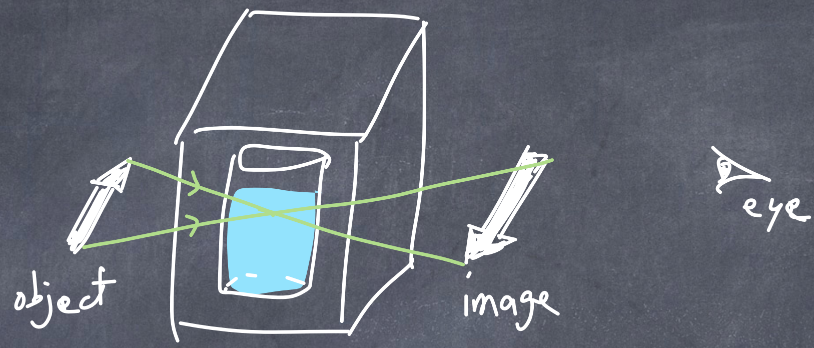
from above:



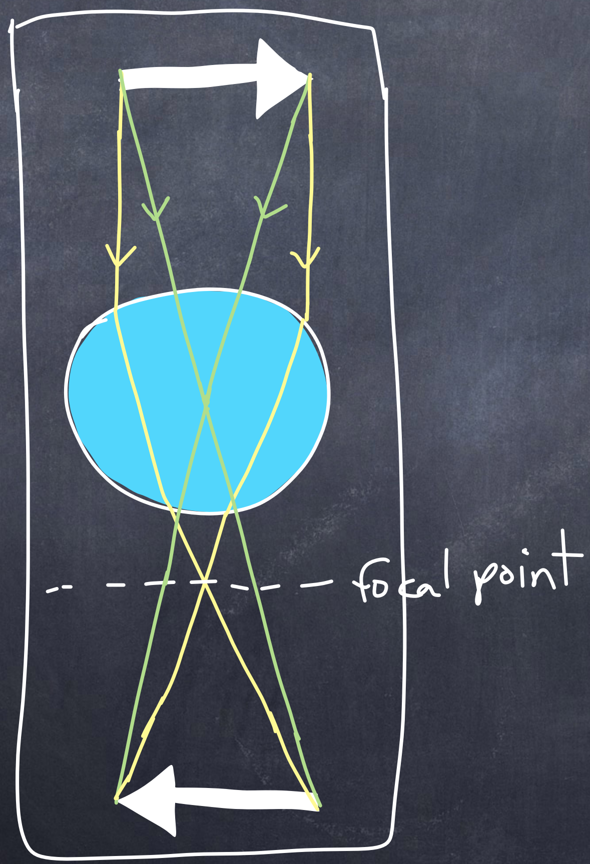


water glass
from above:
focal point
object
image
eye

water glass

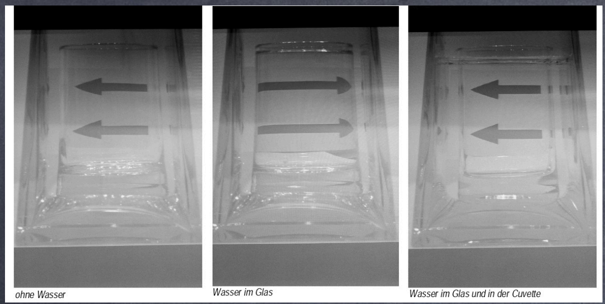


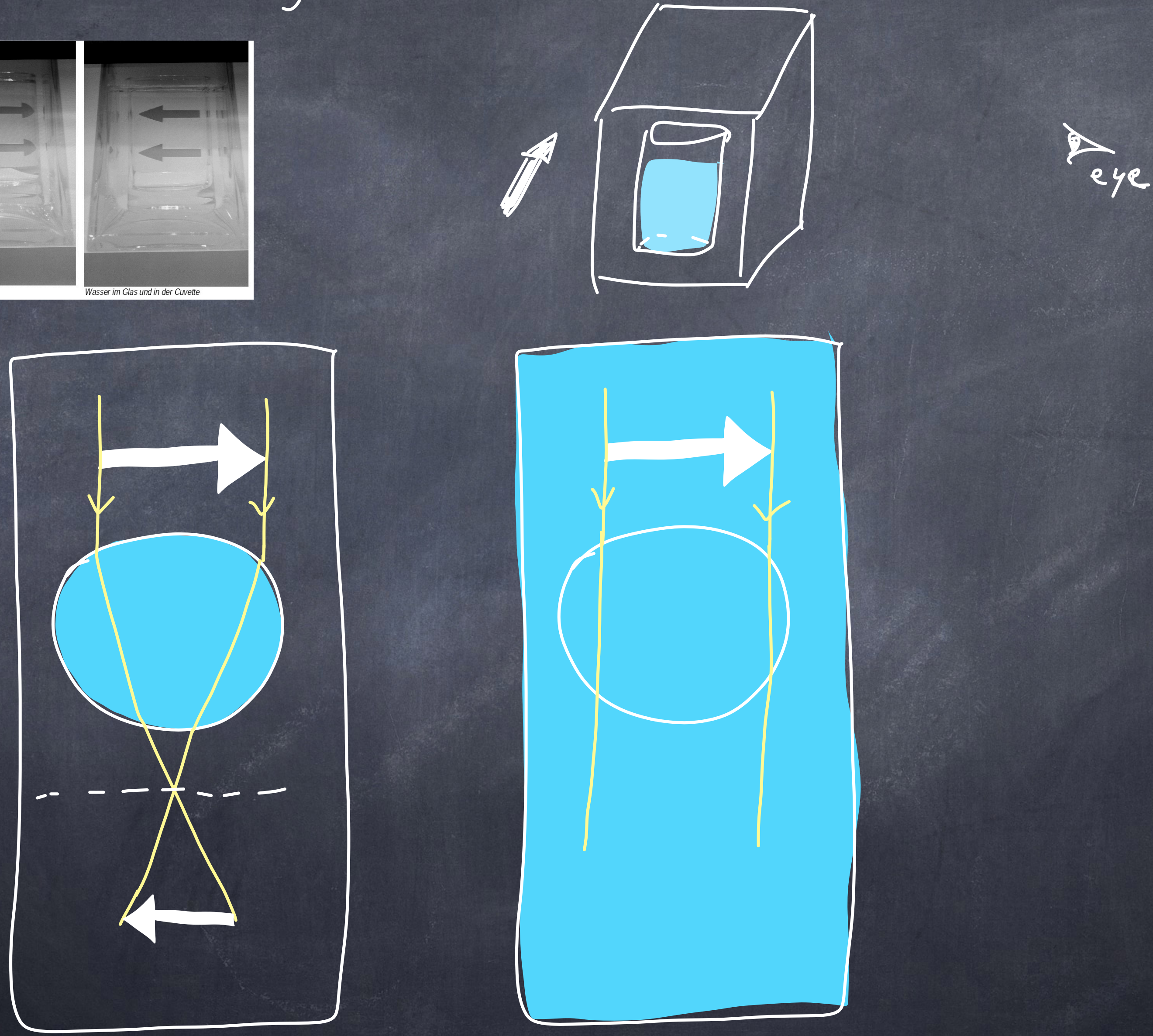
from above:



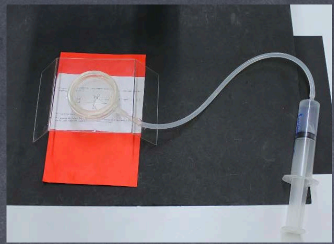
ohne Wasser | Wasser im Glas

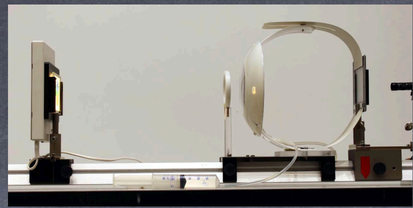
water glass

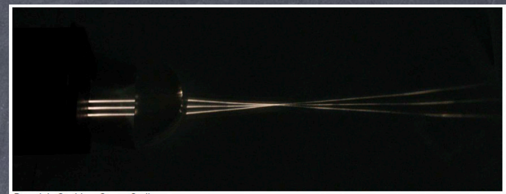

ohne Wasser
Wasser im Glas
Wasser im Glas und in der Cuvette


eye

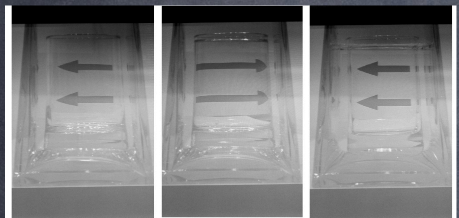

W71


W81

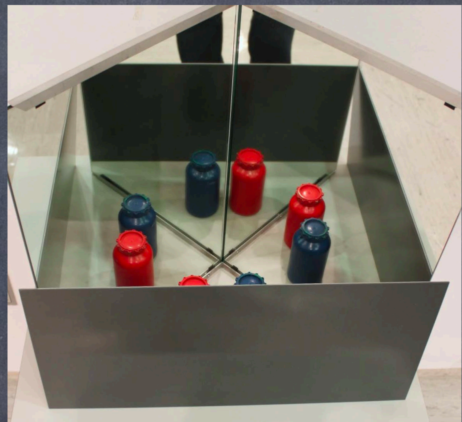

W82

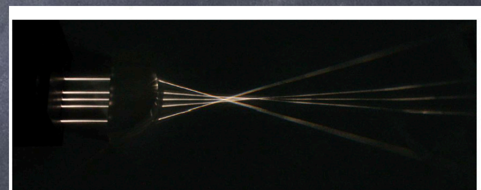

Paraxiale Strahlen; Gauss Optik

W83

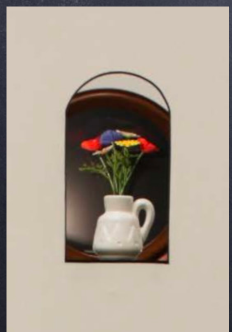

ohne Wasser | Wasser im Glas | Wasser im Glas und in der Cuvette

W88


W69


Sphärische Aberration

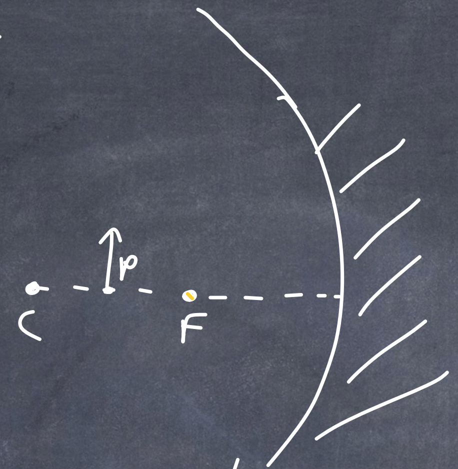
W84


W70


W72


W121

Other example:



where is P'?

where is P'?

s is $+$

s' is $+$

m is $-$ (inverted)

$y' > y$ (image is larger)

$\Rightarrow$ image is real ← inverted ← larger