Image Formation
5.2

Image formation by lenses

Convex lenses

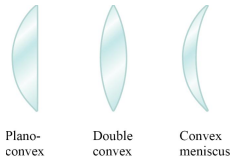
Concave lenses

Image formation by lenses

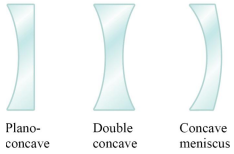
- Images can be formed by lenses that divert light rays by refraction.
- Convex, converging lenses form real images and virtual images- like concave mirrors.
- Concave, diverging lenses only form virtual images, like convex mirrors.
- We discuss the ideal case of thin lenses, i.e. paraxial rays. Real lenses show distortions due to spherical aberration and chromatic aberration.

Convex and Concave Lenses

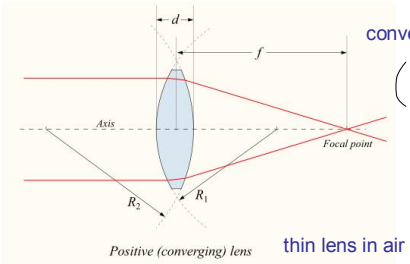
Convex – Converging Lens



Concave – Diverging Lens



Lensmaker's equation



convention on radii R

R is positive

R is negative.

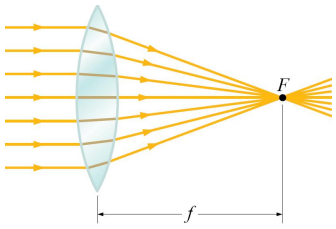
thin lens in air ($d \ll R_1, R_2$)

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

Question

A double convex lens is made out of glass with a refractive index of 1.75. If the radius of curvature of the two surfaces were the same what radius would give a lens with a focal length of f=25 cm?

Convex, Converging Lens

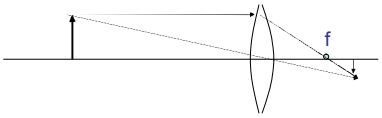


A convex lens converges parallel rays onto a focal point, f.

Focusing by a converging lens

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.



Images formed by a converging lens

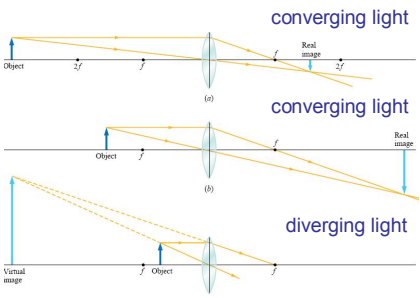
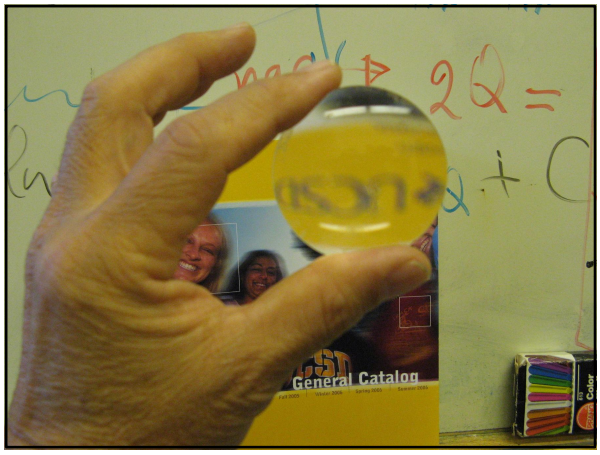


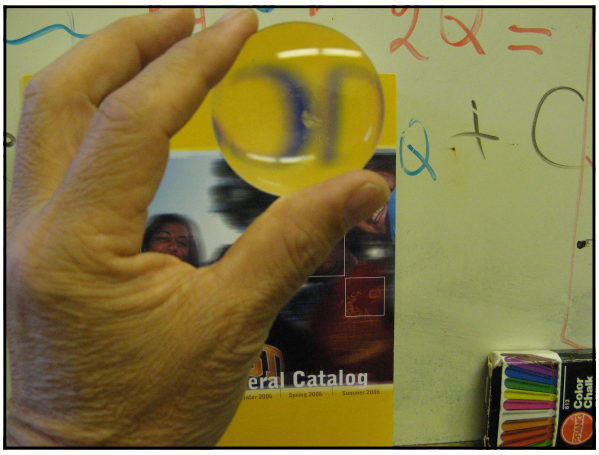
Image formed by a converging lens

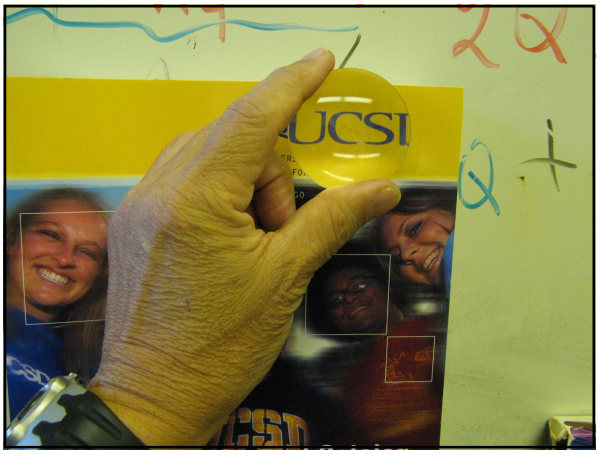
http://micro.magnet.fsu.edu/primer/java/lenses/converginglenses/index.html

Question

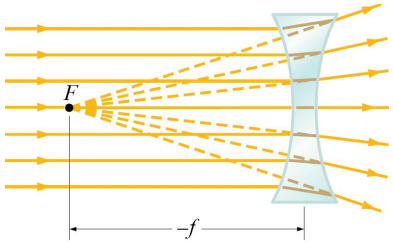
How will an object viewed through a converging lens appear as the lens is brought closer to the object?





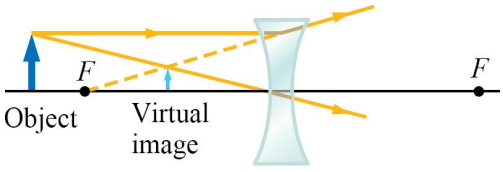


Diverging lens



Diverging parallel rays trace back to the focal point.
The light does not actually pass through the focal point.
You can't make a fire focusing sunlight with a diverging lens.

Image formed by a diverging lens



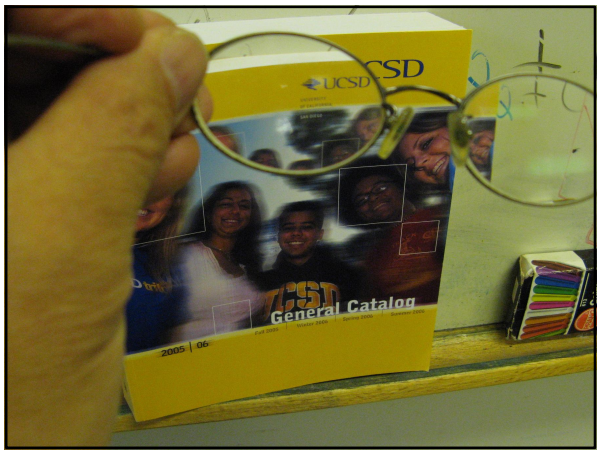
Virtual
Upright
Reduced

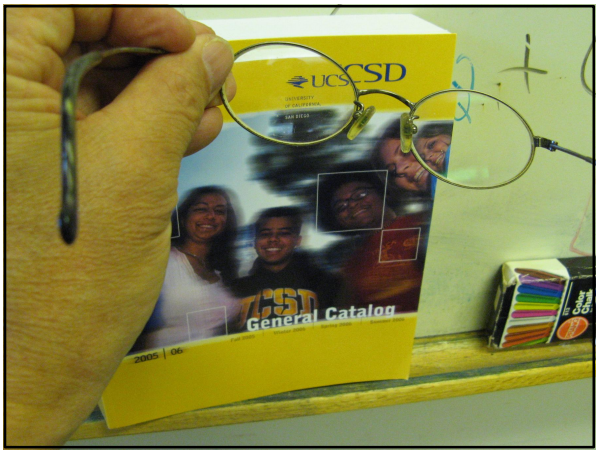
Image formed by a diverging lens

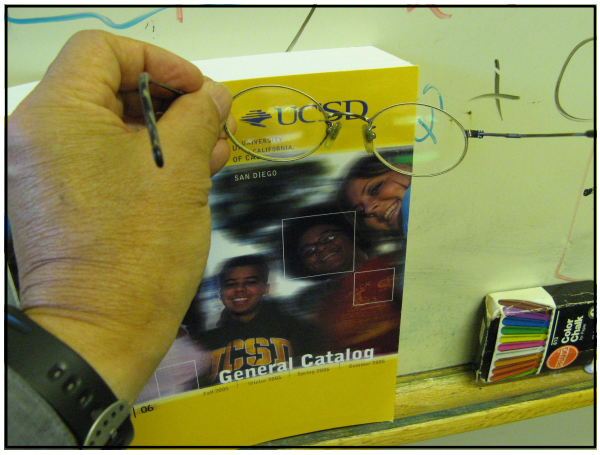
http://micro.magnet.fsu.edu/primer/java/lenses/divinglenses/index.html

Question

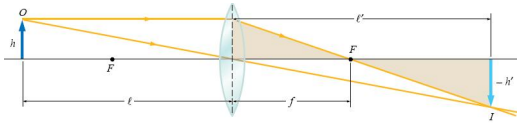
How will the image of an object formed by a diverging lens change as the lens is brought closer to the object?







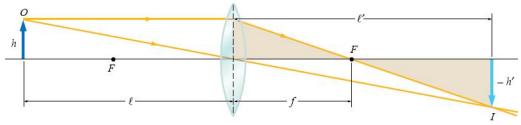
Thin Lens Equation



$$\frac{1}{\ell} + \frac{1}{\ell'} = \frac{1}{f}$$

f is positive for converging lens,
f is negative for a diverging lens.

Magnification

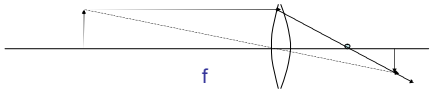


$$m = \frac{h'}{h} = -\frac{\ell'}{\ell}$$

Negative m for an inverted image
Positive m for an upright image

Question

A converging lens with a focal length of 10 cm is placed 30 cm in front of a candle. Find the image distance. Find the magnification.



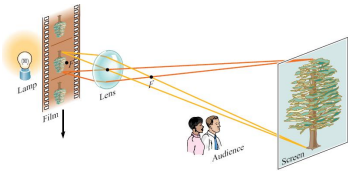
Question

A candle and a screen are 70 cm apart.

Find two points between the candle and screen where you could put a convex lens with a 17 cm focal length to give a sharp image of the candle on the screen.

Find the magnification at the two positions.

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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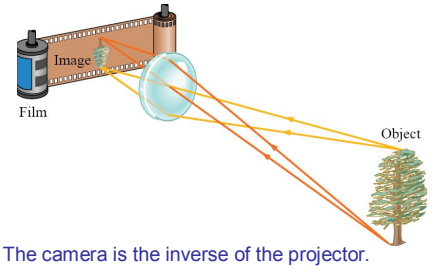
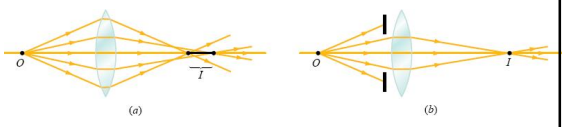
Camera



The camera is the inverse of the projector.
The image and object are reversed

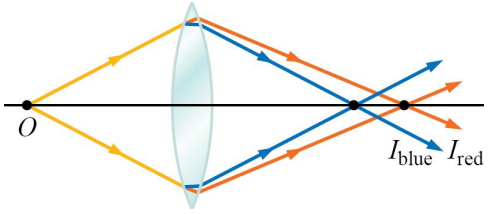
Spherical Aberration



non-paraxial rays

paraxial rays

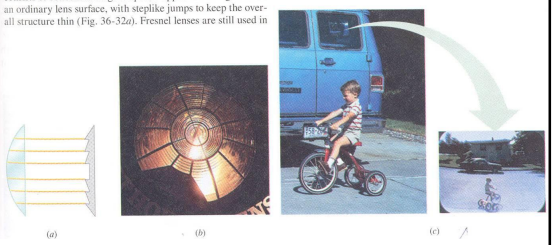
Chromatic Aberration



Fresnel Lens

To solve this problem the French scientist Augustin Fresnel, in 1822, devised a way of making large lenses thin. A Fresnel lens consists of concentric rings shaped to approximate segments of an ordinary lens surface, with steplike jumps to keep the overall structure thin (Fig. 36-32*a*). Fresnel lenses are still used in

are also used in some overhead projectors.



(*a*) (*b*) (*c*)