Phys 112 2019

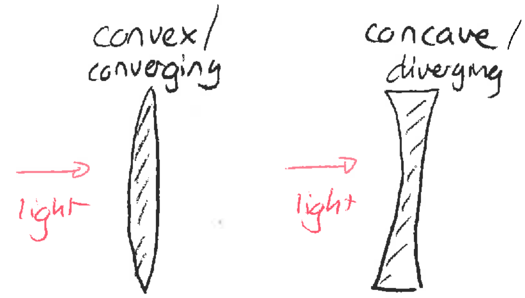
Lecture 30

Mon: Warm Up 12 by 9am

Tues: Discussion /quiz
Supp Ex 110, 111, 112, 113,
Ch 18 Q 19
Ch 18 Prob 20, 21

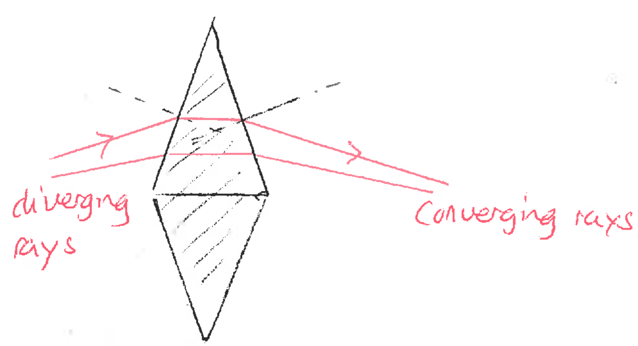
Lenses

A lens is a piece of transparent material with regularly curved interfaces that functions by refracting light rays. We will consider two basic types of lenses:



Demo: BB optics & cross sections

Consider a converging lens. This can be approximated as two prisms and Snell's law can be used to trace rays through these.



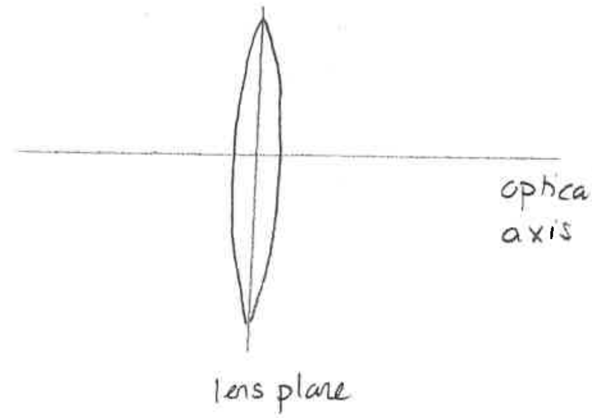
If the lens surfaces are sections of a sphere and the lens is thin then we can approximate Snell's law to attain a mathematical description of how rays pass through the lens

Lens operation

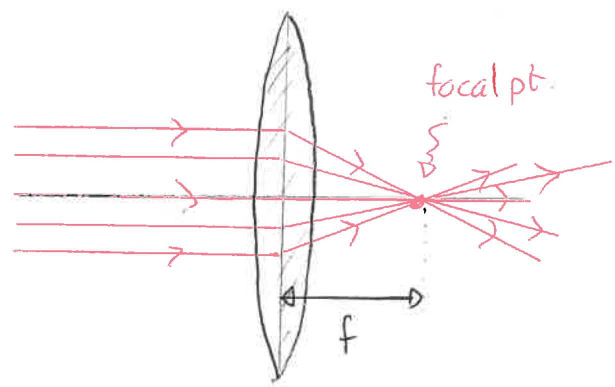
Rather than use Snell's law and trace refraction we can consider certain special light rays. The following ideas are necessary

1) optical axis – line through the center of the lens (and centers of curvature.

2) lens plane – line perpendicular to optical axis through center of lens



3) focal point – all rays (for converging lens.) that travel parallel to the optical axis pass through a single point on the far side of the lens. This is the focal point of the lens.



4) focal length – distance from the lens plane to focal point. Denoted f

Note:

1) the focal point only describes what happens to rays traveling parallel to the optical axis

2) there is a focal point on either side of the lens. These are equally distant from the lens

3) the location of the focal pt depends on

a) curvature of lens

b) index of refraction of lens + surrounding medium.

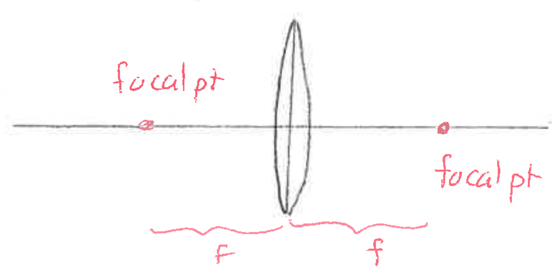
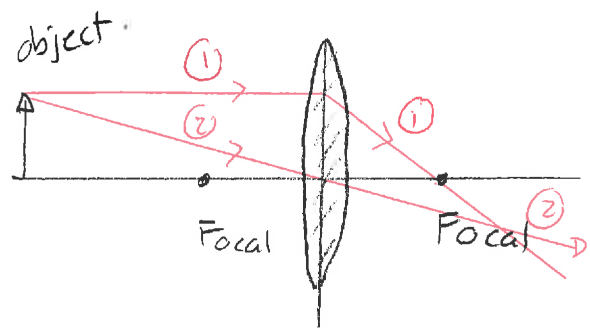


Image formation by a converging lens

We can consider light rays emanating from any point on the object and trace these through the lens. Suppose the object is left of the lens. We trace two rays

Quiz 1



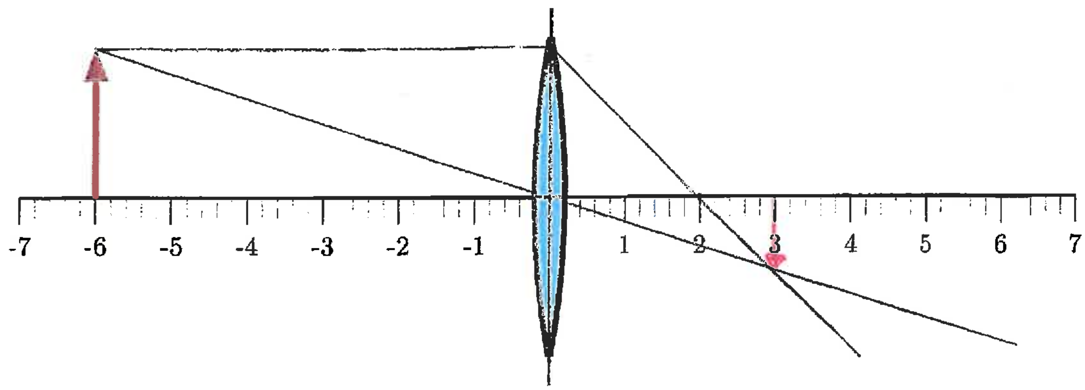
① Ray travels parallel to optical axis and passes through far focal pt.

② Ray passes undeflected through center of lens

The intersection is where the image is located.

124 Image formation by a convex lens: object beyond focal point

A convex lens has focal length 2.0 cm. An arrow with height 2.0 cm is placed 6.0 cm left of the lens.



a) Trace two rays from the tip of the arrow to determine where the image of the tip is produced.

b) Determine the distance from the lens plane to the image of the arrow.

c) Determine the height of the image of the arrow. Determine the magnification

$$m := \frac{h'}{h}$$

where h is the height of the object and h' is the height of the image.

The thin lens equation relates the positions of the object and the image via

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

where s is the distance from the lens to the object and s' is the distance from the lens to the image.

d) Use the thin lens equation to predict the location of the image. Check this against your diagram.

e) The magnification equation predicts

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

Use this to predict the magnification and the height of the image. Check this against your diagram.

b) measuring gives 3cm

c) " " 1cm $h' = -1.0\text{cm}$

$h = 2.0\text{cm}$

$$\Rightarrow \quad M = -\frac{1}{2} = -0.5 \quad \Rightarrow \boxed{M = -0.5}$$

d) $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$

$$\Rightarrow \frac{1}{6} + \frac{1}{s'} = \frac{1}{2} \quad \Rightarrow \quad \frac{1}{s'} = \frac{1}{2} - \frac{1}{6} = \frac{3-1}{6} = \frac{2}{6} = \frac{1}{3}$$

$$\Rightarrow \boxed{s' = 3\text{cm}}$$

matches

e) $M = -\frac{3\text{cm}}{6\text{cm}} = -0.5 \quad \Rightarrow \boxed{M = -0.50}$ matches

$$\frac{h'}{h} = -0.50 \quad \Rightarrow \quad h' = -h\,0.50$$

$$= -2\text{cm} \times 0.50\text{cm} = \boxed{-1.0\text{cm}}$$

matches

Quiz 2 40%

We see that if the object is beyond the focal point of a convex lens then

1) the image is inverted
2) " " is real (light propagates to image)

The image always exists whether a screen is present or not.