Phys 132 2022

Lecture 40

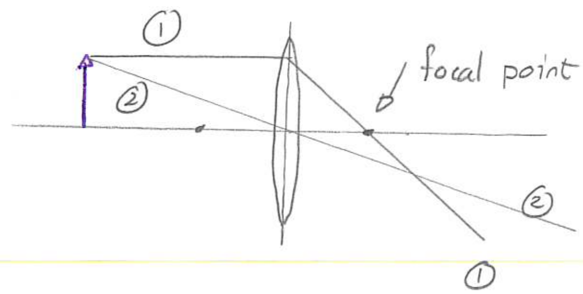
Tues: Warm Up 15 → Part class → Part diagnostic test – max 5pts extra credit – see email

Weds: Discussion Ex 248, 249, 250, 251, 252

Thurs: Review for final

Image production for convex lenses

We have see that images produced by a convex lens can be analyzed by tracing two rays that pass through the lens.



1. parallel to optical axis → pass through focal point
2. directly through center of the lens.

The subsequent parts depend on whether the rays intersect.

1. rays intersect → location of image
2. rays diverge → back trace to get point from which rays appear to emanate.

Quiz1 80% - 100%

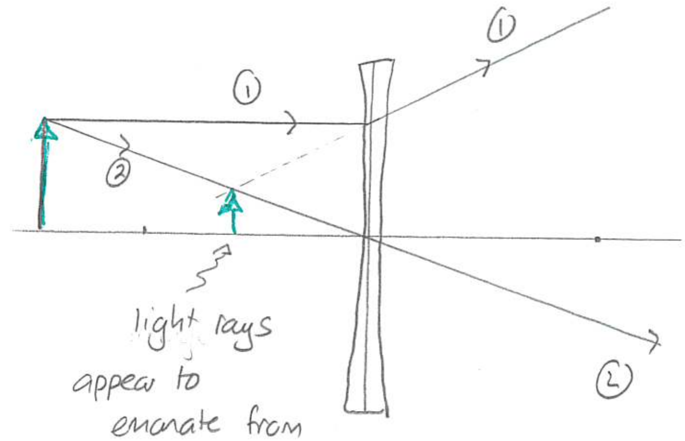
We see two cases:

1) object beyond focal point ⇒ image to right + inverted
⇒ rays arrive at image (real)
⇒ could be smaller larger.

2) " between focal pt + lens ⇒ image on same side as object, upright, larger
rays do not arrive at image - virtual

Image production for concave lenses

In this case trace the same two rays and they always diverge and we have to trace back to locate the image. We see that:



a) image is always between object + lens

b) image is always upright

c) " " " smaller than object

d) light rays do not actually travel to/from image ⇒ image is virtual.

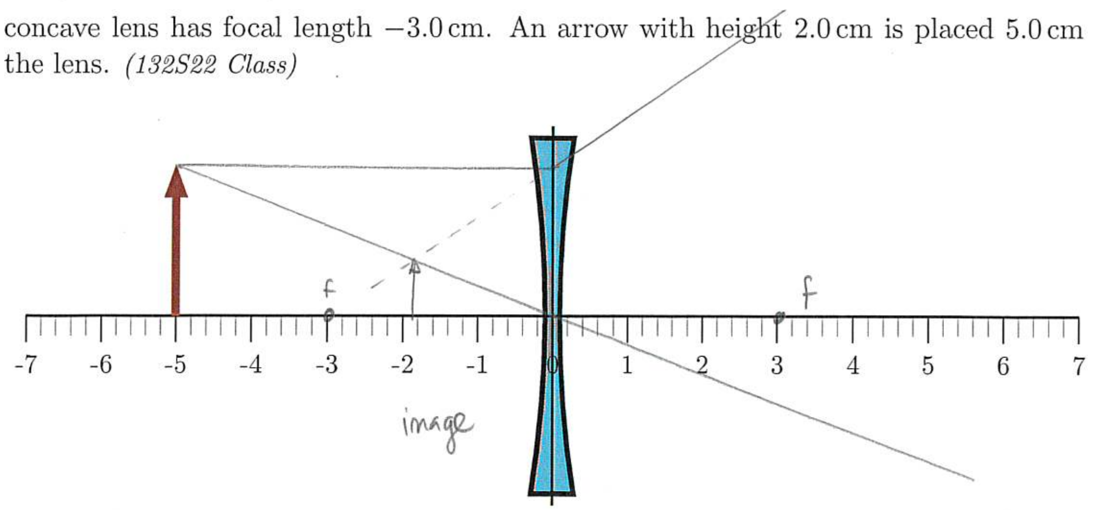
The same thin lens equation can be used but the focal length must be negative

Quizz -80% → 100%

After exercise on next page.

247 Image formation by a concave lens

A concave lens has focal length $-3.0\,\mathrm{cm}$. An arrow with height $2.0\,\mathrm{cm}$ is placed $5.0\,\mathrm{cm}$ left of the lens. *(132S22 Class)*



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.

Answer: a) diagram

b) 1.8cm (here −1.8cm to indicate left)

c) $0.7\,cm = h'$

$$M = \frac{h'}{h} = \frac{0.7\,cm}{2.0\,cm} = 0.35$$

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

$$\frac{1}{5} + \frac{1}{s'} = \frac{1}{-3} \Rightarrow \frac{1}{s'} = -\frac{1}{5} - \frac{1}{3} = -\frac{8}{15}$$

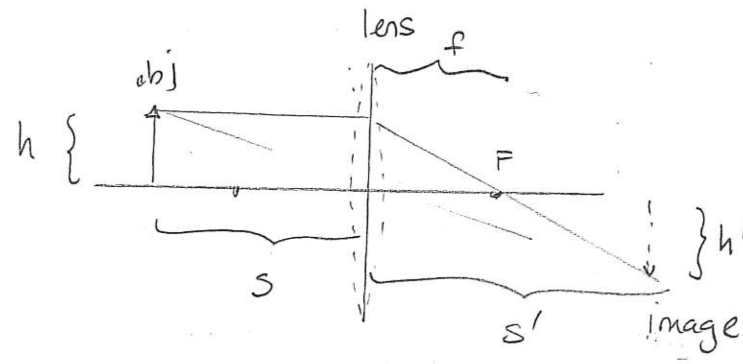
$$\Rightarrow s' = -\frac{15}{8} = -1.88\,cm$$

e) $$M = -\frac{s'}{s} = -\left(\frac{-15/8}{5}\right) = +0.375$$

$$\frac{h'}{h} = 0.375 \Rightarrow h' = 0.375\,h = 0.75\,cm$$

Thin lens equation

The ray tracing method can approximately locate images but it will never be precise. However, there are methods using equations for doing this. The generic set up is.



variable	symbol	conditions
focal length	f	$f>0$ converging lens $f<0$ diverging lens.
object location	s	$s>0$ object to left of single lens
image location	s'	$s'>0$ image on opposite side of lens $s'<0$ image on same side of lens
object height	h	$h>0$
image height	h'	$h'>0$ image upright $h'<0$ image inverted.

Then geometry yields the <u>thin lens equation</u>

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

and the magnification equations: $\boxed{m=\frac{h'}{h}}$ $\boxed{m=-\frac{s'}{s}}$

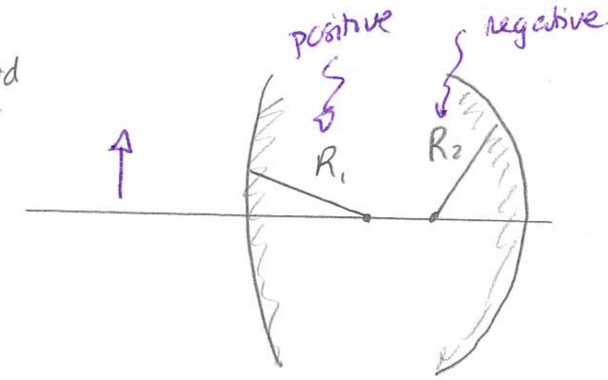
Lens makers equation

How could we determine the focal length of a lens? How could we design a lens with a given focal length?

For lenses with spherical cross-section the focal length depends on:

1) index of refraction of lens material: n_2
2) " " " " surrounding material: n_1
3) radii of curvature of the two surfaces: R_1, R_2
where

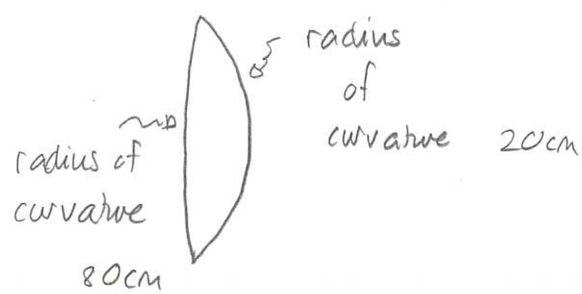
$R_i > 0$ surface convex toward object
$R_i < 0$ " concave ...



Then the lens-makers equation is

$$\boxed{\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

Example: A lens with material with index of refraction 1.33 is placed in air. Determine the focal length of the lens



Answer: $\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$R_1 = 80cm$

$R_2 = -20cm$

$$\frac{1}{f} = (1.33-1)\left(\frac{1}{80cm} - \frac{1}{-20cm}\right) = 0.33 \frac{5}{80cm}$$

$$\Rightarrow f = \frac{80cm}{1.65} = 48cm$$

Quiz3