Quick Notes

Monday, May 10, 2021 1:50 AM

NOTE: This 1st problem involves the Lensmaker's equation, but I don't think this concept will be tested on. Feel free to skip this problem if you'd like.

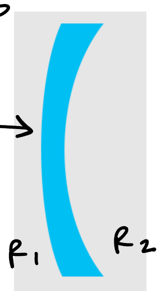
Lensmaker's Equation

An object is placed 90 cm from a glass lens with index of refraction 1.52, with one concave surface of radius 22.0 cm and one convex surface of radius 18.5 cm.

(a) Where is the image located?

(b) What is the magnification?

SHAPE OF LENS



LENSMAKER'S EQN

$$\frac{1}{f} = (\underbrace{n}_{=1.52}-1)\left[\frac{1}{\underbrace{R_1}_{=+18.5\text{ cm}}} + \frac{1}{\underbrace{R_2}_{=-22\text{ cm}}}\right]$$

$$= 0.00447174 \rightsquigarrow f = \frac{1}{0.00447174} = 223.6\text{ cm}$$

LENS EQN

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \rightsquigarrow d_i = \left[\frac{1}{\underbrace{f}_{=+223.6\text{ cm}}} - \frac{1}{\underbrace{d_o}_{=+90\text{ cm}}}\right]^{-1} = \boxed{-150.6\text{ cm}}$$

SAME SIDE AS OBJECT

VIRTUAL

MAGNIFICATION EQN

$$m = -\frac{\overbrace{d_i}^{=-150.6\text{ cm}}}{\underbrace{d_o}_{=+90\text{ cm}}} = \boxed{+1.67}$$

UPRIGHT

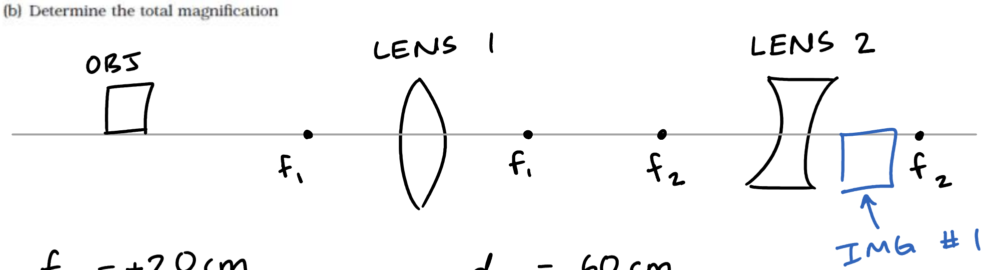
2-Lens System

Two lenses, one converging with focal length 20.0 cm and one diverging with focal length 10 cm, are placed 25.0 cm apart. An object is placed 60.0 cm in front of the converging lens.

(a) Determine the position of the final image

(b) Determine the total magnification

NOTE: DRAWN SOMEWHAT TO SCALE



$f_1 = +20\text{ cm}$

$f_2 = -10\text{ cm}$

DIVERGING

$d_{o_1} = 60\text{ cm}$

$$\frac{1}{\underbrace{d_{o_1}}_{=+60\text{ cm}}} + \frac{1}{d_{i_1}} = \frac{1}{\underbrace{f_1}_{=+20\text{ cm}}} \rightsquigarrow d_{i_1} = +30\text{ cm}$$

OPP. SIDE AS OBJECT

$= +60\,cm$ $\qquad +20\,cm \qquad$ AS OBJECT

REAL, INVERTED (CHECK MAGNIFICATION m_1)

SINCE $d_i = 30\,cm > 25\,cm$, THE OBJECT FOR THE 2^{ND} LENS IS BEHIND THE LENS.

BEHIND 2^{ND} LENS

$$d_{o_2} = -5\,cm$$

$$\frac{1}{d_{o_2}} + \frac{1}{d_{i_2}} = \frac{1}{f_2} \rightarrow d_{i_2} = \Big[\underbrace{\frac{1}{f_2}}_{=-10\,cm} - \underbrace{\frac{1}{d_{o_2}}}_{=-5\,cm}\Big]^{-1} = \boxed{+10\,cm}$$

SAME SIDE AS OBJECT

BEHIND 2^{ND} LENS

$$m_1 = -\frac{\overbrace{d_{i_1}}^{=+30\,cm}}{\underbrace{d_{o_1}}_{=-60\,cm}} = -0.5$$

IMG #1 IS INVERTED

$$m_2 = -\frac{\overbrace{d_{i_2}}^{=+10\,cm}}{\underbrace{d_{o_2}}_{=-5\,cm}} = +2$$

IMG # 2 IS UPRIGHT

TOTAL MAGNIFICATION

$$M = \underbrace{m_1}_{=-0.5}\underbrace{m_2}_{=+2} = -1.0$$

FINAL IMG IS INVERTED

Do you think the image is real or virtual? With respect to Lens #2, its object and its image are both on the same side. Typically, this means that the image is virtual. However, since we have a 2-lens system, we have to **refine our sign convention**.

- d_o is positive when the object is on the **same side as the incoming light** (from the left).
- d_i is positive when the image is on the **opposite side as the incoming light** (from the left); and positive d_i means real image.

Since the final image is behind the 2nd lens (on the very right side), we see that the d_i is on the opposite side of the incoming image, and thus d_i is positive and the image is real.

Old-School Projectors (picture)

Suppose an elderly couple wishes to see their old wedding photos. They bring out a slide projector to create a 98 cm-tall upright image of themselves from a 2 cm-tall slide. The screen is 3 m from the slide. Assuming the projector uses a thin lens,

(a) Would the image be $\boxed{\text{real}}$ or virtual?

(a) What focal length does the lens need?

(b) How far should the lens be placed from the slide?

The image should be **real** because the image forms on the OPPOSITE side as the incoming light (d_i is **positive**)

NOTE: The slides (photos) are placed upside-down into the projector so that the resulting image is upright!

$h_o = -2\,cm$ $\qquad d_i \qquad h_i \overset{+98\,cm}{=} -49\,cm$

NOTE: The slides (photos) are placed upside-down into the projector so that the resulting image is upright!

$h_o = -2$ cm → UPSIDE-DOWN

$h_i = +98$ cm → UPRIGHT

$m = -\dfrac{d_i}{d_o} = \dfrac{\overset{+98\text{cm}}{h_i}}{\underset{-2\text{cm}}{h_o}} = -49$ cm → INVERTED (UPRIGHT)

→ $d_i = +49\,d_o$

So weird!!! this is because we typically associate "inverted" with being "upside-down", but really the definition of inverted is "opposite" relative to the object. Since the object is initially upside-down, inverting this would mean upright!

$|d_o| + |d_i| = 3m$

$\longrightarrow |d_o| + |\overset{+49d_o}{d_i}| = 50\,|d_o| = 3m$

→ $\boxed{|d_o| = 0.06m = 6\text{ cm}}$

$d_o = \pm 6$ cm

OPP. SIDE OF INCOMING LIGHT

$d_i = +49d_o > 0$

→ IMPLIES $d_o > 0$ AND THUS $d_o = +6$cm

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \rightsquigarrow f = \left[\frac{1}{\underset{+6\text{cm}}{d_o}} + \frac{1}{\underset{+294\text{cm}}{d_i}}\right]^{-1} = \boxed{+5.88\text{ cm}}$$

→ CONVERGING