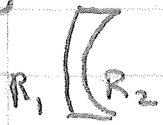
Physics 302 Photonics

HW-4 Chapter 5 SOLUTIONS

(5.12)



$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = (1.5-1)\left(\frac{1}{20.0\,\text{cm}} - \frac{1}{10.0\,\text{cm}}\right)$$

$f = -40\,\text{cm}$, diverging lens.

$$\frac{1}{S_i} = \frac{1}{f} - \frac{1}{S_o} = \frac{1}{-40\,\text{cm}} - \frac{1}{20\,\text{cm}} \Rightarrow \boxed{S_i = -\frac{40}{3}\,\text{cm}}$$

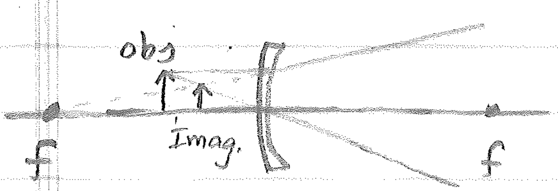
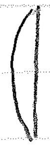


Image is virtual, erect, smaller.

(5.22)



(a)

$$\frac{1}{f} = (1.5-1)\left(\frac{1}{50.0\,\text{mm}} - \frac{1}{\infty}\right)$$

$$\boxed{f = +100\,\text{mm}}$$

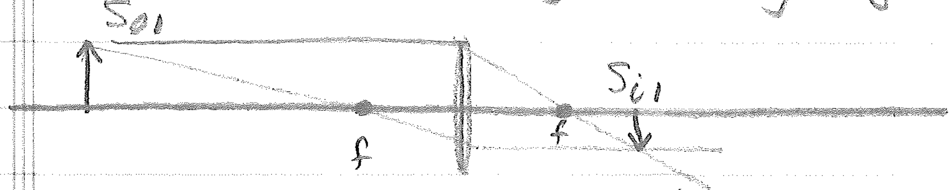
(b) If in water, $\frac{1}{f} = \left(\frac{n_g - n_w}{n_w}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$= \left(\frac{1.5-1.33}{1.33}\right)\left(\frac{1}{50.0\,\text{mm}} - \frac{1}{\infty}\right)$$

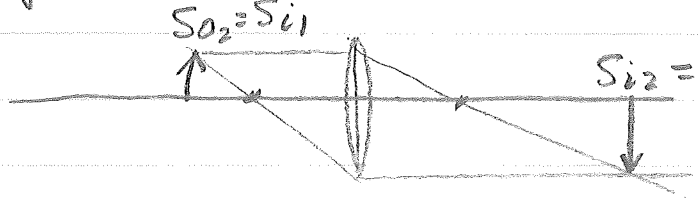
$$\boxed{f = +391\,\text{mm}}$$

The focal length increases. In the limit as the index of refraction of the liquid approaches the index of refraction of the glass, the focal length becomes infinite, ie, it acts like a glass slide, no focusing.

(5.32) Consider following placing obj. at S_{o1} ⇒ image at S_{i1}



Since rays are reversible, consider placing obj. at a distance $S_{o2} = S_{i1}$ ⇒ image at $S_{i2} = S_{o1}$



Evidently $S_{o1} - S_{o2} = S_{i2} - S_{i1}$

So $L \equiv S_{o1} + S_{i1} = S_{o2} + S_{i2}$

lens eq: $\frac{1}{f} = \frac{1}{S_{o1}} + \frac{1}{S_{i1}} \Rightarrow f = \frac{S_{o1} S_{i1}}{S_{o1} + S_{i1}} = \frac{S_{o1} S_{i1}}{L}$

The distance between the two positions of the lens is:

$$d = S_{o1} - S_{o2} = S_{i2} - S_{i1}$$

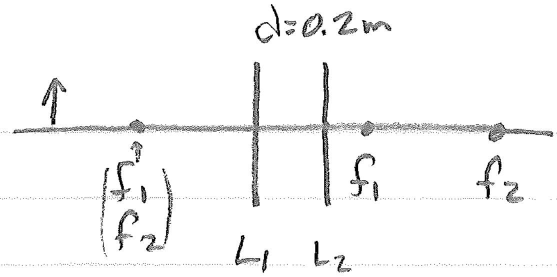
Now form $L^2 - d^2 = (S_{o1} + S_{i1})^2 - (S_{o1} - S_{o2})^2$

But $S_{o2} = S_{i1}$ from above, so

$L^2 - d^2 = 4 S_{o1} S_{i1}$. Put this into eq. above for f:

$$\Rightarrow \boxed{f = \frac{L^2 - d^2}{4L}}$$

5.33



1st Lens: $\frac{1}{S_{i_1}} = \frac{1}{f_1} - \frac{1}{S_{o_1}} = \frac{1}{0.3\,m} - \frac{1}{0.5\,m} \Rightarrow S_{i_1} = +0.75\,m$

2nd Lens: $\frac{1}{S_{i_2}} = \frac{1}{f_2} - \frac{1}{S_{o_2}}$ But $S_{o_2} = -S_{i_1} + d$

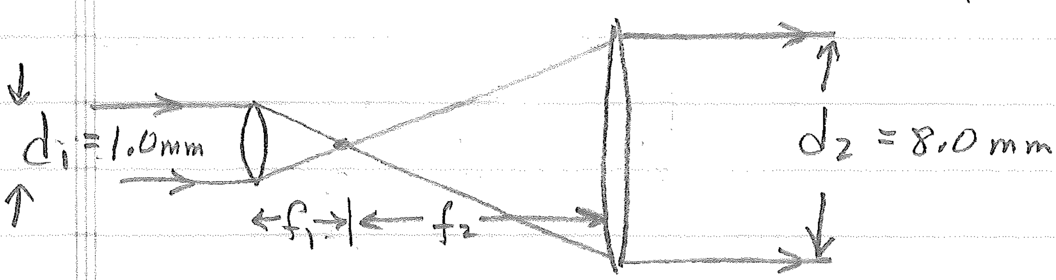
$$= -0.75\,m + 0.2\,m$$

$$S_{o_2} = -0.55\,m$$

$$\Rightarrow \frac{1}{S_{i_2}} = \frac{1}{0.5\,m} - \frac{1}{-0.55\,m} \Rightarrow \boxed{S_{i_2} = 0.262\,m}$$

This is the distance from lens 2, ie, on the right side, w/erect image

5.40 To act as a beam expander, the lenses must be placed so that their focal points coincide:



The two triangles are similar so $\frac{d_1}{f_1} = \frac{d_2}{f_2}$

or $f_2 = \frac{d_2}{d_1} f_1 = \left(\frac{8.0\,mm}{1.0\,mm}\right)(50.0\,mm) = \boxed{400\,mm = f_2}$

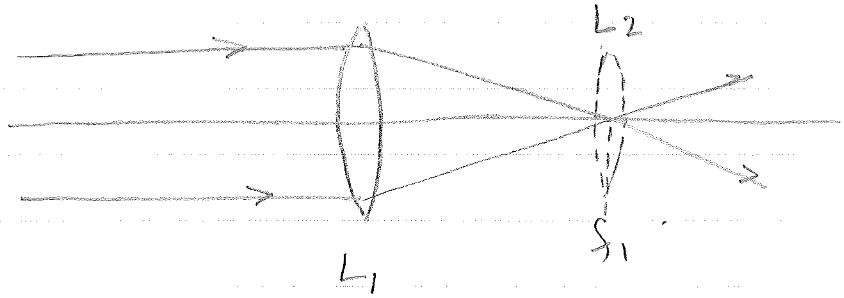
Separation $\equiv D = f_1 + f_2 = 50.0\,mm + 400\,mm$

$$\boxed{D = 450\,mm}$$

The focal points of L1 and L2 must coincide as shown in order to have parallel entrance rays become parallel exit rays.

(5.42)

As we discussed in class, this problem should say "... the magnification of a distant object does not change."



If a second lens is placed at f_1, all rays (from the distant object) will pass thru its center, and hence will be undeviated and unmagnified as seen in the diagram.