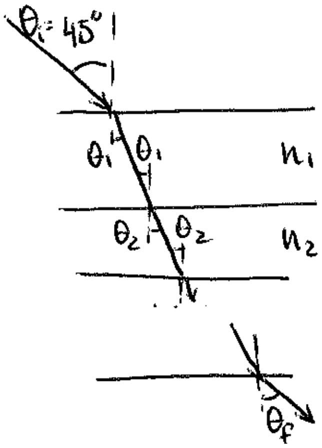
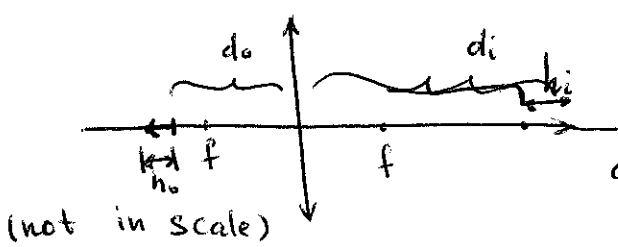
Problem set #2 (solutions)



In case light is transmitted through the stack, it emerges at the same angle as it enters, since on each boundary the Snell's law makes $\sin\theta_i = n_1 \sin\theta_1 = n_2 \sin\theta_2 = \ldots = \sin\theta_f$

In principle, it may be possible that if the refractive index b/w two layers is dramatically different, such that $n_1 \sin\theta_1 > n_2$, the total internal reflection occures. However, in reality all glasses have $n \simeq 1.4 \div 1.6$, ~~so that~~ and the propagation angle is relatively sharp ($\lesssim 30°$), so ~~it is in~~ the light will travel through (but partially reflecting at each surface).

3. 4



Notice that since the object is horisontal, the magnification must be calculated separately

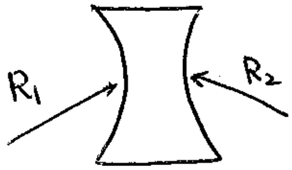
$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \qquad \frac{1}{d_o + h_o} + \frac{1}{d_i + h_i} = \frac{1}{f}$$

$$d_i = \frac{d_o \cdot f}{d_o - f} \qquad d_i + h_i = \frac{(d_o + h_o) \cdot f}{d_o + h_o - f}$$

In our case $h_o \ll (d_o - f)$, so $d_i + h_i \simeq \frac{(d_o \cancel{h_o}) f}{d_o - f} - h_o \frac{f^2}{(d_o - f)^2}$

$$h_i = -\frac{h_o \cdot f^2}{(d_o - f)^2} = -1.6\,m$$

3.9



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

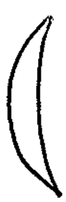
For concave surfaces both $R_1, R_2 < 0$
I.e. each surface makes light more diverging, reducing the absolute value of the focal length

$$\frac{1}{f} = (1.65-1)\left(\frac{1}{(-25\,cm)} + \frac{1}{(-45\,cm)}\right) = -\,24.7\ cm$$

A1.

#1  plano convex
$R_1 = \infty \quad R_2 > 0$ } converging, $f>0$

#2  bi convex
$R_1, R_2 > 0$, $f > 0$ converging (sortest focal length)

#3  meniscus
$R_1 > 0$, $R_2 < 0$, but $|R_1| < |R_2|$ and $\frac{1}{R_1} + \frac{1}{R_2} > 0$
converging

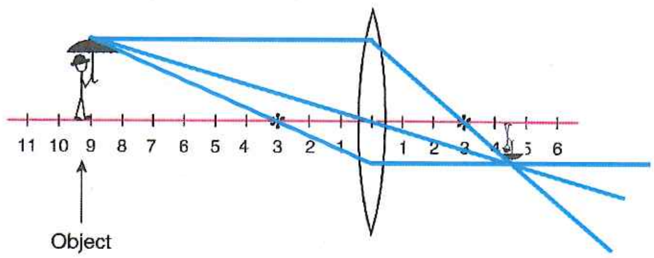
#4  planoconcave
$R_1 = \infty \quad R_2 < 0$, $f < 0$ diverging

#5  negative meniscus
$R_1 < 0$, $R_2 > 0$, but $|R_1| < |R_2|$, and $\frac{1}{R_1} + \frac{1}{R_2} < 0$
diverging

#6 Same as #2, but R_1, R_2 are larger than in #2, so $f_{\#6} > f_{\#2}$

A2. The following lens has a focal length f=3cm (Foci are marked *) Draw the "magic rays" and find the position of the image graphically, and then use the lens formula to verify your results for the two object distances below. What is the magnification in each case?

(a)



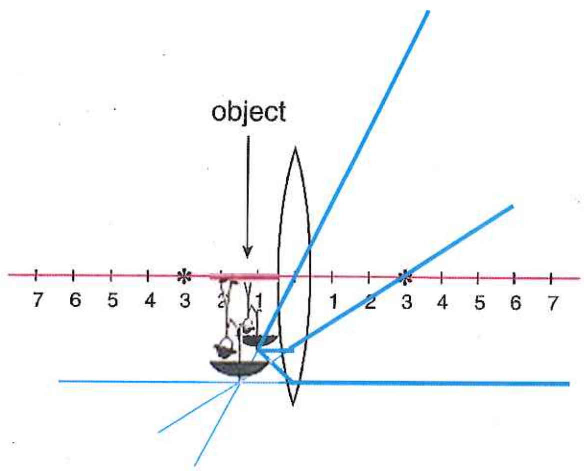
$$d_i = \frac{d_o \cdot f}{d_o - f} = \frac{9cm \cdot 3cm}{6cm} = 4.5cm$$

$d_i > 0$ real image

$$m = -\frac{d_i}{d_o} = -\frac{4.5cm}{9cm} = -\frac{1}{2}$$

inverted

(b)



$$d_i = \frac{d_o \cdot f}{d_o - f} = \frac{1.2cm \cdot 3cm}{-1.8cm} = -2cm$$

$d_i < 0$ virtual image

$$m = -\frac{d_i}{d_o} = \frac{2cm}{1.2cm} = 1.67$$

erect

A3. Show the three "magic rays" from the top of the object through the lens. The symbol * marks the focal length on either side of the lens. Describe the image (real vs virtual, erect vs inverted).