1. A Thick lens problem

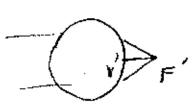
$$M_{vv'} = \begin{pmatrix} 1 - P'\frac{D}{n} & -P - P' + \frac{DPP'}{n} \\ \frac{D}{n} & 1 - P\frac{D}{n} \end{pmatrix}$$

where
$$P = \frac{n-1}{R}$$
$$P' = +\frac{n-1}{R}$$
$$D = 2R$$

$$M_{vv'} = \begin{pmatrix} 1 - \frac{2(n-1)}{n} & -\frac{2(n-1)}{R} + \frac{2R(n-1)^2}{R^2 n} \\ \frac{2R}{n} & 1 - \frac{2(n-1)}{n} \end{pmatrix}$$

$$M_{vv'} = \begin{pmatrix} \frac{2-n}{n} & -\frac{2(n-1)}{R}\left(1 - \frac{n-1}{n}\right) \\ \frac{2R}{n} & \frac{2-n}{n} \end{pmatrix} = \begin{pmatrix} \frac{2-n}{n} & -\frac{2(n-1)}{nR} \\ \frac{2R}{n} & \frac{2-n}{n} \end{pmatrix}$$

(a)



$$\tilde{M}_{12} = M_{12}$$

$$\tilde{M} = \begin{pmatrix} 1 & 0 \\ s' & 1 \end{pmatrix} \begin{pmatrix} & M_{vv'} & \end{pmatrix} \begin{pmatrix} 1 & 0 \\ s & 1 \end{pmatrix} = \begin{pmatrix} \tilde{M}_{11} & -\frac{2(n-1)^2}{nR} \\ \tilde{M}_{21} & \tilde{M}_{22} \end{pmatrix}$$

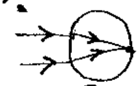
$$\tilde{M}_{21} = m_{11} s' + m_{12} s s' + m_{21} + m_{22} s = 0 \quad \text{for make}$$

$$s \to \infty \qquad s' = F'V = -\frac{m_{22}}{m_{12}} = -\frac{2-n}{n} \times \left(-\frac{nR}{2(n-1)}\right) = \frac{2-n}{n-1} \times \frac{R}{2}$$

$$F'V = \frac{2-n}{n-1} \times \frac{R}{2} \qquad n = \frac{3}{2} = 1.5$$

(a) $$F'V = \frac{0.5}{0.5} \times \frac{R}{2} = \frac{R}{2}$$

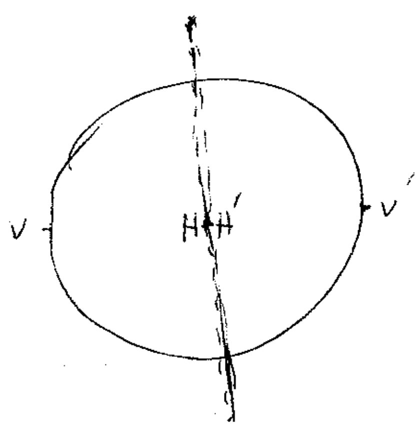
Note: for $n=2$
$F'V=0$, The rays are
focused into back
surface at V'.



(b) $$P_e = P_{sys} = P + P' - PP'\frac{D}{n} = \frac{2(n-1)}{R} - \frac{(n-1)^2 \times 2R}{R^2 n}$$

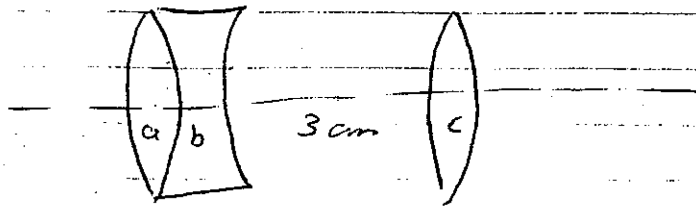
$$= \frac{2(n-1)}{nR}$$

$$D' = D = \frac{P'D}{-P_e n} = \frac{\frac{n-1}{R} \times 2R}{-\frac{2(n-1)}{nR}\, n} = \qquad = -R$$



(c) $$f' = \frac{1}{P} = \frac{nR}{2(n-1)}$$

2 (ICF # 3.49)



$$M_{sys} = M^c \, T_{bc} \, M^b \, M^a$$

for each lens (since $R_1 = -R_2$) we have

$$M^j = \begin{pmatrix} 1 - \frac{n_j - 1}{n_j}\frac{D}{R} & \frac{2(1-n_j)}{R} + \frac{(1-n)^2}{R^2}\frac{D}{n_j} \\ \frac{D}{n_j} & 1 - \frac{n_j - 1}{n_j}\frac{D}{R} \end{pmatrix}$$

where $R = +15$ cm for lenses $\underline{a}$ and $\underline{c}$, and $R = -15$ for lens $\underline{b}$

$D = 0.5$ for all $\quad n_a = 1.5 \quad n_b = 1.3 \quad n_c = 1.6$

and $T_{bc} = \begin{pmatrix} 1 & 0 \\ 3_{cm} & 1 \end{pmatrix}$

* Note: We have assumed here that lenses (a) and (b) are both (surrounded) by air ($n' = 1$, $n = 1$). The result is the same as taking $n = 1$, $n' = n_b$ for lens (a) and $n = 1$, $n' = 1$ for lens (b). The former method is easier.

Using Math Cad:

$$M_{sys} = \begin{pmatrix} 0.699 & -0.097 \\ 4.015 & 0.87 \end{pmatrix}$$

$$P_{sys} = -M_{12} = 0.097 \ cm^{-1} = 9.7 \ m^{-1}$$

D (diopter)

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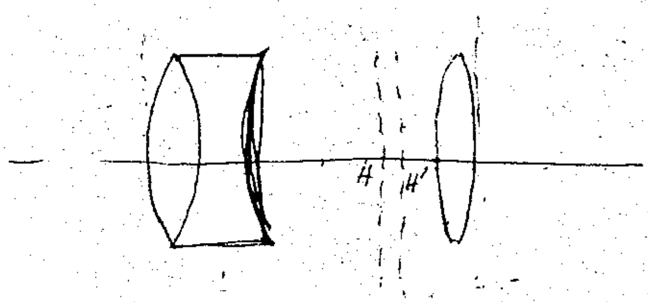
* Principal planes

$$D = \frac{1 - M_{11}}{M_{12}} = -3.1$$

$$D' = \frac{1 - M_{22}}{M_{12}} = -1.34$$



Note $HH' = 4.5 - 4.44 = 0.06$ cm

0.6 mm

3 (K&F 3.56)

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

$$\frac{1}{s} + \frac{1}{L-s} = \frac{1}{f} \Rightarrow s^2 - sL + Lf = 0$$

$$s = \frac{L \pm \sqrt{L^2 - 4Lf}}{2}$$

Note $L^2 - 4Lf > 0$ $\boxed{L > 4f}$

$$\left.\begin{aligned} \Rightarrow s_1 &= \frac{L + \sqrt{L^2 - 4Lf}}{2} \\ \Rightarrow s_2 &= \frac{L - \sqrt{L^2 - 4Lf}}{2} \end{aligned}\right\} |s_1 - s_2| = \underline{d} = \sqrt{L^2 - 4Lf}$$