PHYS302 Fall 2023

Homework 4

1. 4.98 from Hecht
2. Using the index of refraction, explain why silver is a good reflector for visible light but glass is not. (Note that the index of refraction of silver is given in problem 4.95.)
3. 5.6 from Hecht
4. 5.10 from Hecht
5. 5.12 from Hecht
6. 5.32 from Hecht
7. (E.C.) 5.37 from Hecht

Note: For problems asking for a ray diagram (5.10, 5.12, and 5.32), please draw at least 2 principal rays. Remember that a principal ray either goes through the lens vertex or is, at some point, parallel to the optical axis.

HW #4

① (4.98)

trace	color of rose
1	"light" pink
2	orange
3	white
4	red
5	"dark" pink
6	yellow
7	blue

② Reflectance is given by

$$R = \left(\frac{\hat{n}-1}{\hat{n}+1}\right)\left(\frac{\hat{n}-1}{\hat{n}+1}\right)^* = \frac{(n_R-1)^2 + n_I^2}{(n_R+1)^2 + n_I^2}$$

for complex $\hat{n} = n_R - i\, n_I$

Silver: Like most metal in VIS, $n_I \gg n_R$ for silver.

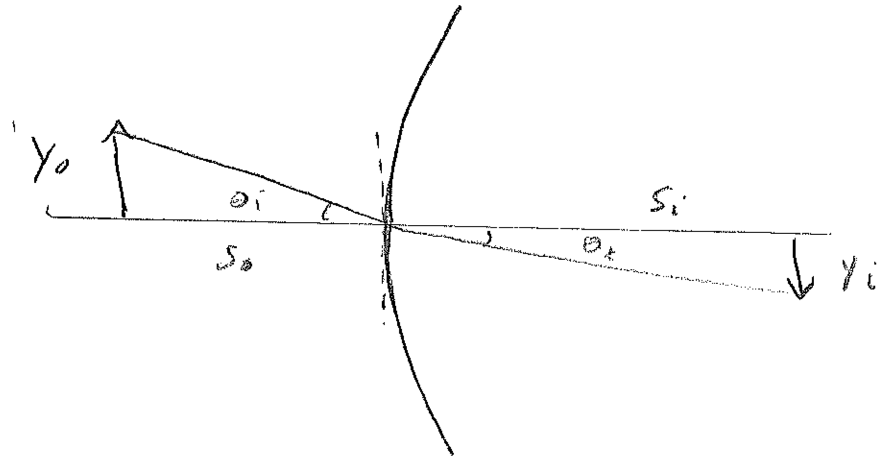
$$R \approx \frac{n_I^2}{n_I^2} \approx 1$$

(For actual R at ~500 nm, $R = \frac{(0.15-1)^2 + 2^2}{(0.15+1)^2 + 2^2} \approx 0.89$, ~90% of light is reflected)

Glass: $n_R \approx 1.5$ & $n_I \approx 0$ in VIS

$$R = \frac{(1.5-1)^2}{(1.5+1)^2} \approx 0.04$$ ← only ~4% of light reflected

③ (5.6)



From picture: y_i is negative so $-y_i = |y_i|$.

$$\tan\theta_i = \frac{y_o}{s_o} \approx \theta_i \quad \& \quad \tan\theta_t = \frac{-y_i}{s_i} \approx \theta_t$$ (small angle approx.)

$$M_T = \frac{y_i}{y_o} = \frac{-s_i\theta_t}{s_o\theta_i}$$ ← using $\sin\theta_t n_2 = \sin\theta_i n_1$

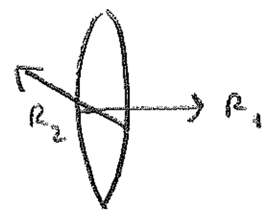
⇓

$n_2\theta_t = n_1\theta_i$ (small angle)

$$\boxed{M_T = -\frac{s_i n_1}{s_o n_2}}$$

(4) (5.10) $n_\ell = 1.5$, $f = +10.0\,cm$, $|R_1| = |R_2|$

Biconvex → $R_1 = -R_2$:



$$\frac{1}{f} = (n_\ell - 1)\left(\frac{1}{R_1} - \frac{-1}{R_1}\right) = 0.5\,\frac{2}{R_1} = \frac{1}{10.0\,cm}$$

$$\boxed{R_1 = 10.0\,cm = -R_2}$$

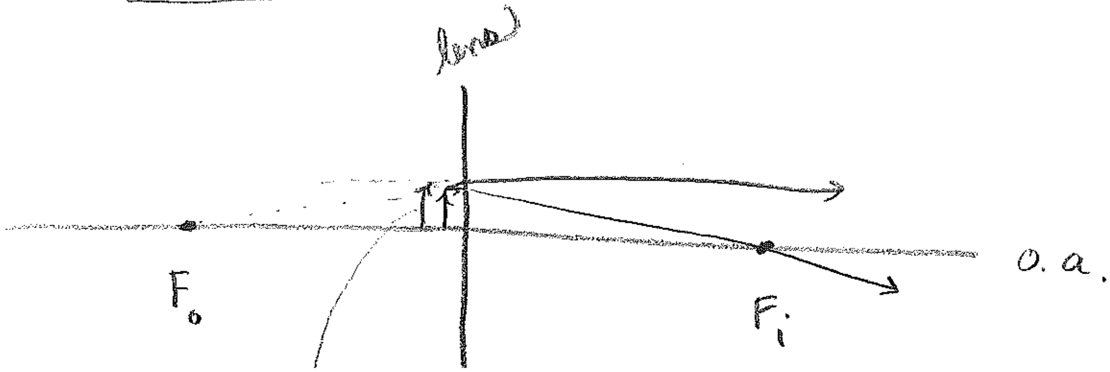


image: upright & virtual

$$\frac{1}{f} = \frac{1}{S_o} + \frac{1}{S_i}$$

$$\frac{1}{10.0\,cm} = \frac{1}{1.0\,cm} + \frac{1}{S_i} \Rightarrow \boxed{S_i \approx -1.1\,cm}$$

$$\boxed{M_T = \frac{-S_i}{S_o} = 1.1}$$

⑤ (5.12)

$n_\ell = 1.5$

meniscus concave →

where $R_1 > R_2$

$R_1 = +\ 20.0\text{ cm}$

$R_2 = +10.0\text{ cm}$

Focal length:

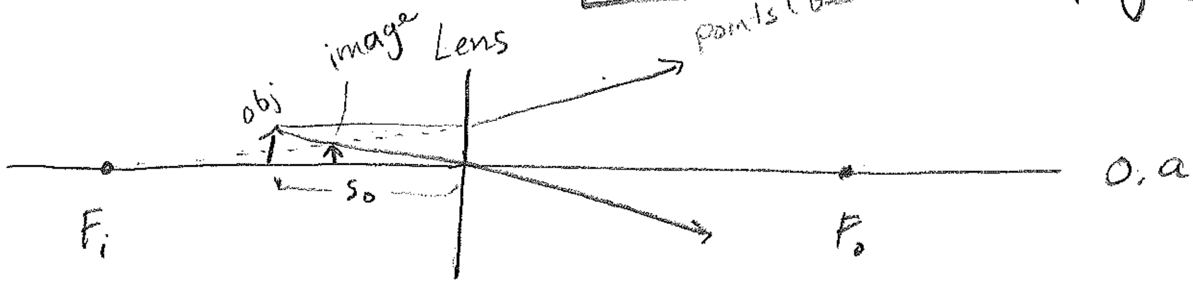
$$\frac{1}{f} = (1.5-1)\left[\frac{1}{20.0} - \frac{1}{10.0}\right]\text{cm}^{-1} = \frac{-0.5}{20.0\text{ cm}}$$

$$\boxed{f = -40.0\text{ cm}}$$

$$\frac{1}{S_i} = \frac{1}{f} - \frac{1}{S_o} = \frac{1}{-40.0\text{ cm}} - \frac{1}{20.0\text{cm}}$$

$$\boxed{S_i = \frac{-40.0\text{ cm}}{3} \approx -13.3\text{ cm}} \qquad M_T = \frac{-(-13.3\text{cm})}{20.0\text{ cm}} = \boxed{0.67}$$

↑ virtual   upright



⑥ (5.32)

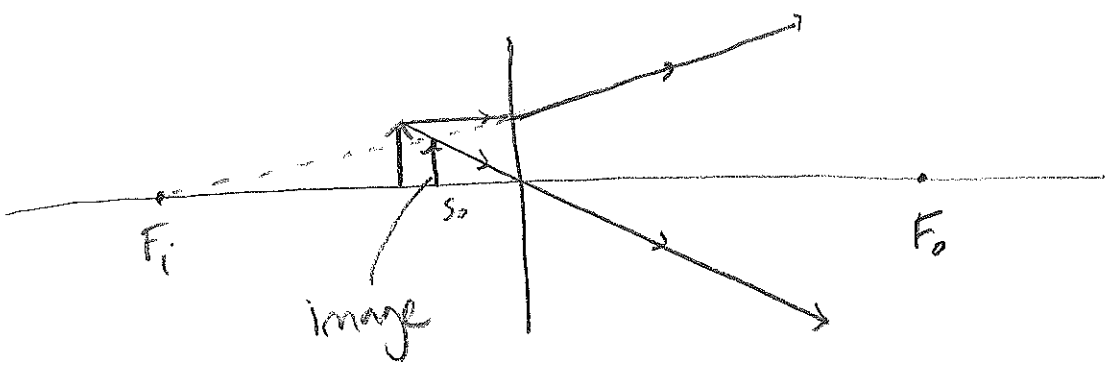
$y_o = 6.00$ cm

$f = -30$ cm

$s_o = 10$ cm

$$\frac{1}{s_i} = \frac{1}{f} - \frac{1}{s_o} = \frac{1}{-30\text{cm}} - \frac{1}{10\text{cm}} = \frac{-4}{30\text{cm}}$$

$$\boxed{s_i = -7.5 \text{ cm}}$$



virtual & upright

$$M_T = -\frac{-7.5}{10} = \boxed{0.75} = \frac{y_i}{y_o}$$

$$\boxed{y_i = 4.50 \text{ cm}}$$

(7) (5.37)

$y_o = 4.00$ mm

$s_o = 60.0$ cm

$y_i = 2.00$ m

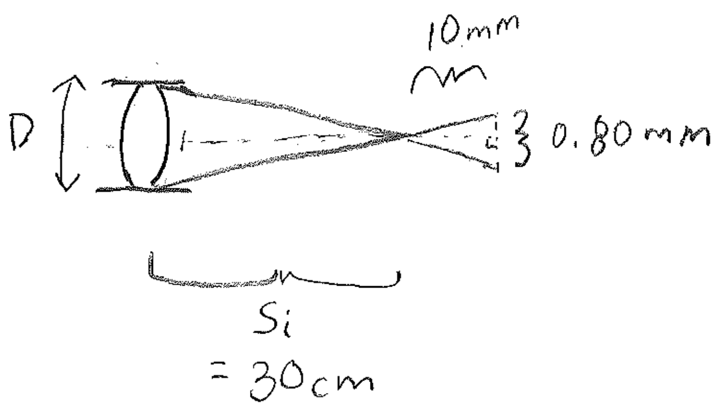
$\rightarrow M_T = \frac{-y_i}{y_o} = -0.5 = \frac{-s_i}{s_o}$

$s_i = 0.5 \cdot 60.0\text{ cm} = \underline{30.0\text{ cm}}$ ← The wire is imaged on a screen ⇒ real image; $s_i > 0$ & $M_T < 0$.

$\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{60.0\text{ cm}} + \frac{1}{30.0\text{ cm}} = \frac{3}{60.0\text{ cm}} = \frac{1}{20.0\text{ cm}}$

$\boxed{f = 20.0\text{ cm}}$

Looking from top, after lens:



Similar triangles:

$\frac{D}{0.80\text{ mm}} = \frac{300\text{ mm}}{10.0\text{ mm}}$

$\boxed{D = 24\text{ mm}}$