

$$\theta_1 = \sin^{-1} \left( \frac{1}{1.3} \cdot \sin 45^\circ \right) = 32.95^\circ$$

$$\theta_2 = \sin^{-1} \left( \frac{1.3}{1.5} \cdot \sin 32.95^\circ \right) = 28.12^\circ$$

$$\theta_3 = \sin^{-1} \left( \frac{1.5}{1.33} \cdot \sin 28.12^\circ \right) = 32.11^\circ$$

$$\theta_4 = \sin^{-1} \left( \frac{1.33}{1} \sin 32.11^\circ \right) = 44.99^\circ \sim 45^\circ$$

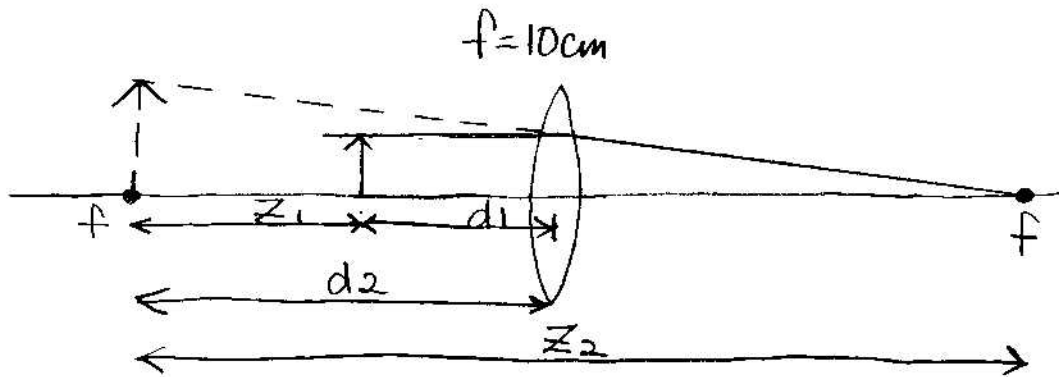
$$\theta_{c2 \rightarrow 3} = \sin^{-1} \left( \frac{1.33}{1.5} \right) = 62.46^\circ$$

$$\theta_{c3 \rightarrow \text{Air}} = \sin^{-1} \left( \frac{1}{1.33} \right) = 48.75^\circ$$

(a) No. ( $\theta_2 < \theta_{c2 \rightarrow 3}$  &  $\theta_3 < \theta_{c3 \rightarrow \text{Air}}$ )

(b)  $\theta_4 \cong 45^\circ$

2.



Gaussian ( $d_1 = -5\text{ cm}$ ,  $f = 10\text{ cm}$ )

$$\frac{1}{d_2} = \frac{1}{d_1} + \frac{1}{f} = \frac{1}{-5} + \frac{1}{10}$$

$$\Rightarrow d_2 = -10\text{ cm}$$

$$M = d_2/d_1 = -10\text{ cm}/-5\text{ cm} = 2$$

$$\bar{M} = M^2 = 4$$

Newtonian ( $f = 10\text{ cm}$ ,  $z_1 = 5\text{ cm}$ )

$$z_1 z_2 = f^2$$

$$z_2 = \frac{f^2}{z_1} = -\frac{10^2}{5} = -20\text{ (cm)}$$

$$d_2 = z_2 + f$$

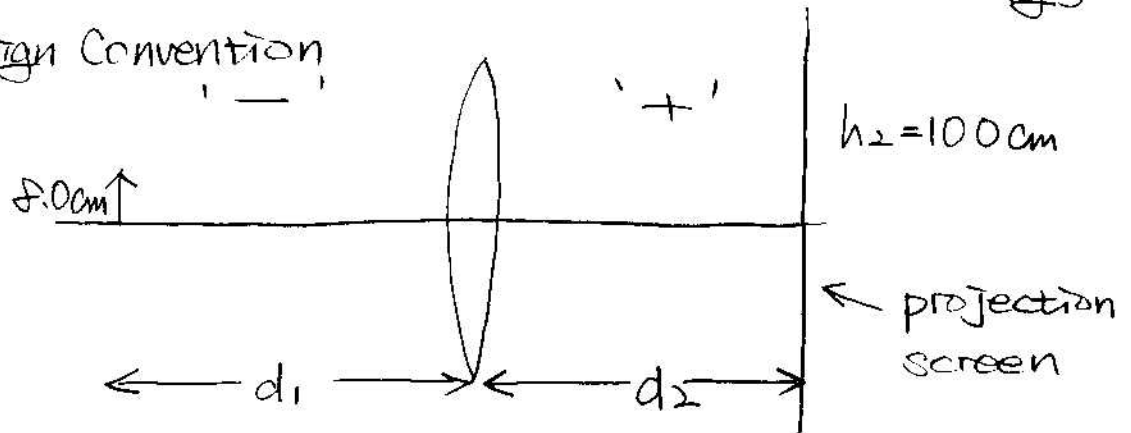
$$= -20 + 10 = -10\text{ (cm)}$$

$$M = -f/z_1 = 10/5 = 2$$

$$\bar{M} = M^2 = 4$$

(I used the sign-convention given in Hecht, Pg 162-163, which is slightly different from the lecture note. Either way, you will get the correct answers.)

## 3. Sign Convention



$$M = \frac{h_2}{h_1} = \frac{|100|}{f} = 12.5 = \left| \frac{d_2}{d_1} \right|$$

$$|d_1| + |d_2| = 350 \text{ (cm)}$$

$$d_2 = -12.5 \cdot d_1$$

$$\Rightarrow |d_1| + 12.5|d_1| = 350$$

$$\Rightarrow |d_1| = 25.9 \text{ cm} \Rightarrow |d_2| = 12.5(25.9) = 324.1 \text{ cm}$$

$$d_1 = -25.9 \text{ cm}, \quad d_2 = 324.1 \text{ cm}$$

$$\frac{1}{d_2} = \frac{1}{d_1} + \frac{1}{f} \rightarrow \frac{1}{f} = \frac{1}{d_2} - \frac{1}{d_1}$$

$$f = +23.98 \text{ cm}$$

Use lens-maker's eqn.

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

For symmetric lens,  $R_1 = -R_2$ .

bi-convex

$$\text{If } n_e = 1.5, \\ R_1 = -R_2 = f = 23.98 \text{ cm}$$