UCA Department of Physics and Astronomy

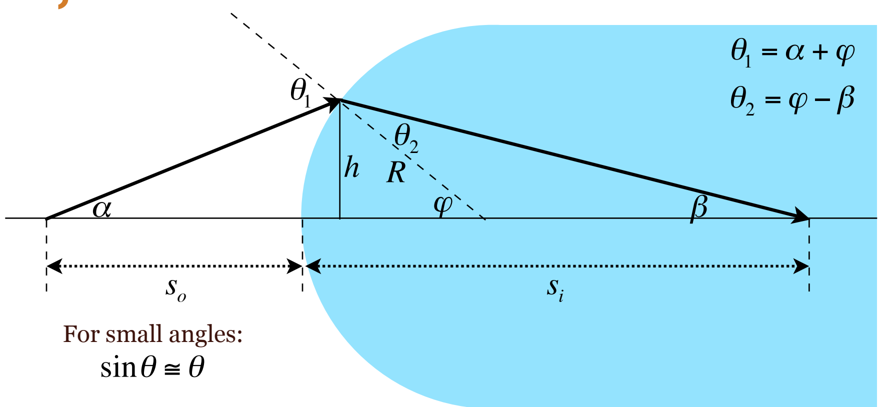
PHYS 3345: OPTICS

Assignment 06: Chapter 05 — Spring 2008

DUE: February 29, 2008

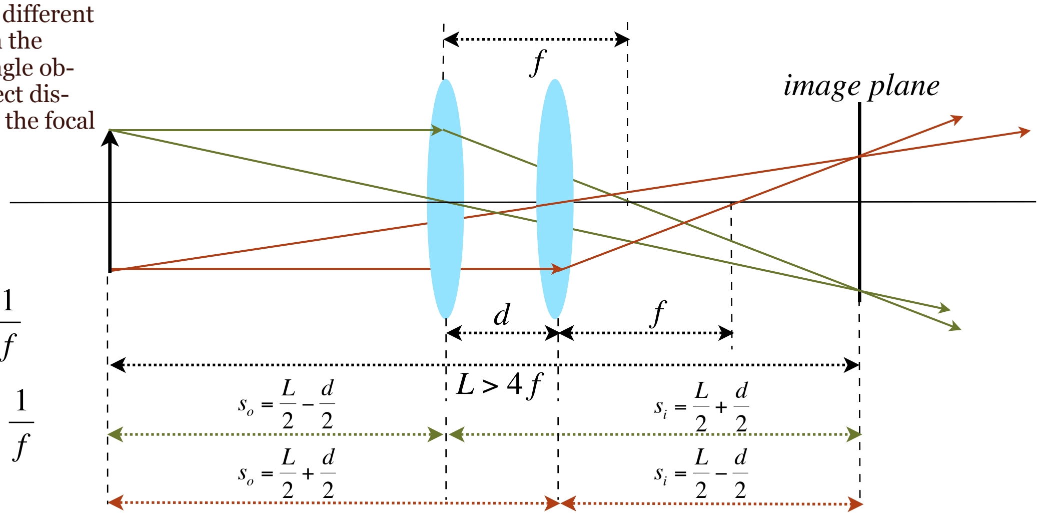
1. Hecht, Problem 5.5

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$
$$n_1 \sin(\alpha+\varphi) = n_2 \sin(\varphi-\beta)$$
$$n_1(\alpha+\varphi) = n_2(\varphi-\beta)$$
$$n_1\left(\frac{h}{s_o}+\frac{h}{R}\right) = n_2\left(\frac{h}{R}-\frac{h}{s_i}\right)$$
$$n_1\left(\frac{1}{s_o}+\frac{1}{R}\right) = n_2\left(\frac{1}{R}-\frac{1}{s_i}\right)$$
$$\frac{n_1}{s_o}+\frac{n_2}{s_i} = \frac{(n_2-n_1)}{R}$$



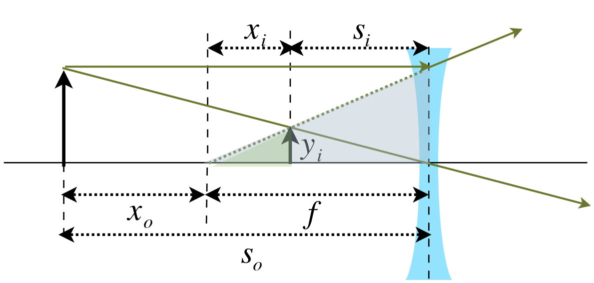
In the paraxial region: $\alpha \approx \dfrac{h}{s_o}$ $\quad \varphi \approx \dfrac{h}{R}$ $\quad \beta \approx \dfrac{h}{s_i}$

2. Hecht, Problem 5.32
The figure shows how two different lens locations can result in the same image plane for a single object location when the object distance is large compared to the focal length of the lens,



$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$$
$$\frac{2}{(L-d)}+\frac{2}{(L+d)}=\frac{1}{f}$$
$$\frac{2(L+d)+2(L-d)}{(L+d)(L-d)}=\frac{1}{f}$$
$$f=\frac{L^2-d^2}{4L}$$

3. For a diverging lens, construct a derivation of Newton's lens equation: $x_o x_i = f^2$.



$$\frac{y_i}{s_i}=\frac{y_o}{s_o}$$
$$\frac{y_i}{f-x_i}=\frac{y_o}{f+x_o}$$
$$\frac{y_i}{x_i}=\frac{y_o}{f}$$

$$\frac{y_i}{y_o}=\frac{f-x_i}{f+x_o}=\frac{x_i}{f}$$
$$f(f-x_i)=x_i(f+x_o)$$
$$f^2=x_o x_i$$

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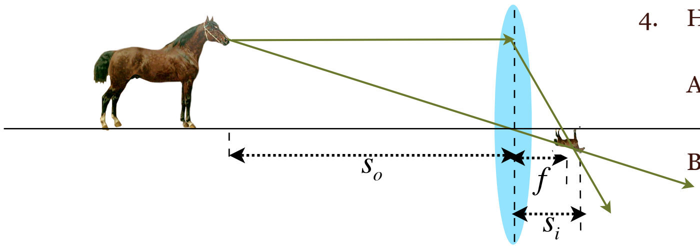


4. Hecht, Problem 5.24

A) $\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$ $\quad \frac{1}{15\text{m}}+\frac{1}{s_i}=\frac{1}{3\text{m}}$ $\quad s_i = 3.75\text{m}$

B) Real, inverted, minified image.

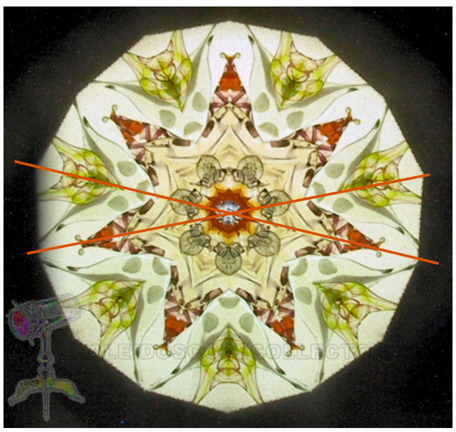
$$M=-\frac{s_i}{s_o}=-\frac{3.75}{15}=-0.25$$

C) $\frac{y_i}{y_o}=-\frac{s_i}{s_o}$ $\quad \frac{y_i}{2.25\text{m}}=-\frac{3.75\text{m}}{15\text{m}}$

$$y_i=-0.563\text{m}$$

D) $\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$ $\quad \frac{1}{17.5\text{m}}+\frac{1}{s_i}=\frac{1}{3\text{m}}$

$s_i = 3.62\text{m}$ $\quad \Delta s = 0.13\text{m}$



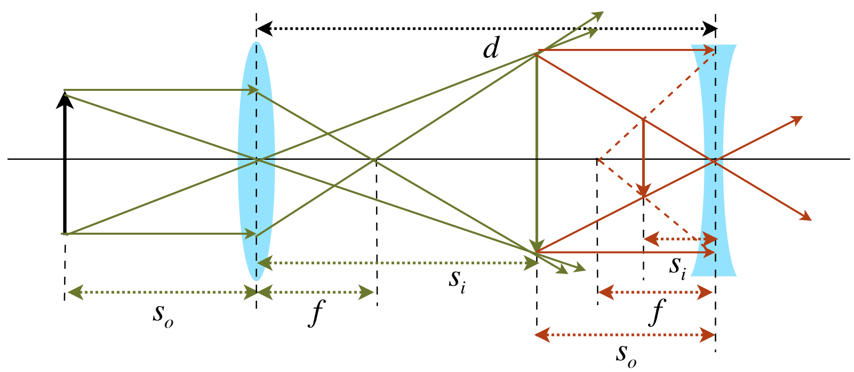
6. The image above are taken from the same two-mirror kaleidoscope. What is the angle between the mirrors?

$$\theta=\frac{360°}{14}=25.7°$$

7. You are constructing a kaleidoscope using *three* mirrors instead of two. The three mirrors are to be joined to form a triangle in the barrel of the scope. To achieve a perfectly symmetric set of images (i.e., there are no fractional images, or cut-off portions), what are the allowable mirror geometries? Explain! Sketches work well here.

For perfect symmetry, the angle between any two mirrors must divide 360° evenly. But for any triangle, the angles must add up to 180°. This leaves you with only a few geometries: an equilateral triangle (60°–60°–60°), an isosceles right triangle ((45°–45°–90°), and a (30°–60°–90°) right triangle.

5. Hecht, problem 5.38.



$$s_o = 25.0\text{cm}$$
$$f_1 = 15\text{cm}$$
$$d = 60.0\text{cm}$$
$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$$
$$\frac{1}{25\text{cm}}+\frac{1}{s_i}=\frac{1}{15\text{cm}}$$
$$s_i = 37.5\text{cm}$$
$$M_1=-\frac{s_i}{s_o}=-\frac{37.5}{25.0}=-1.5$$

$$s_o=(60.0-37.5)\text{cm}=22.5\text{cm}$$
$$f_2=-15\text{cm}$$
$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f}$$
$$\frac{1}{22.5\text{cm}}+\frac{1}{s_i}=-\frac{1}{15\text{cm}}$$
$$s_i=-9.0cm$$
$$M_2=-\frac{s_i}{s_o}=-\frac{-9.0}{22.5}=+0.40$$
$$M=M_1M_2=(-1.5)(0.40)$$
$$M=-0.60$$