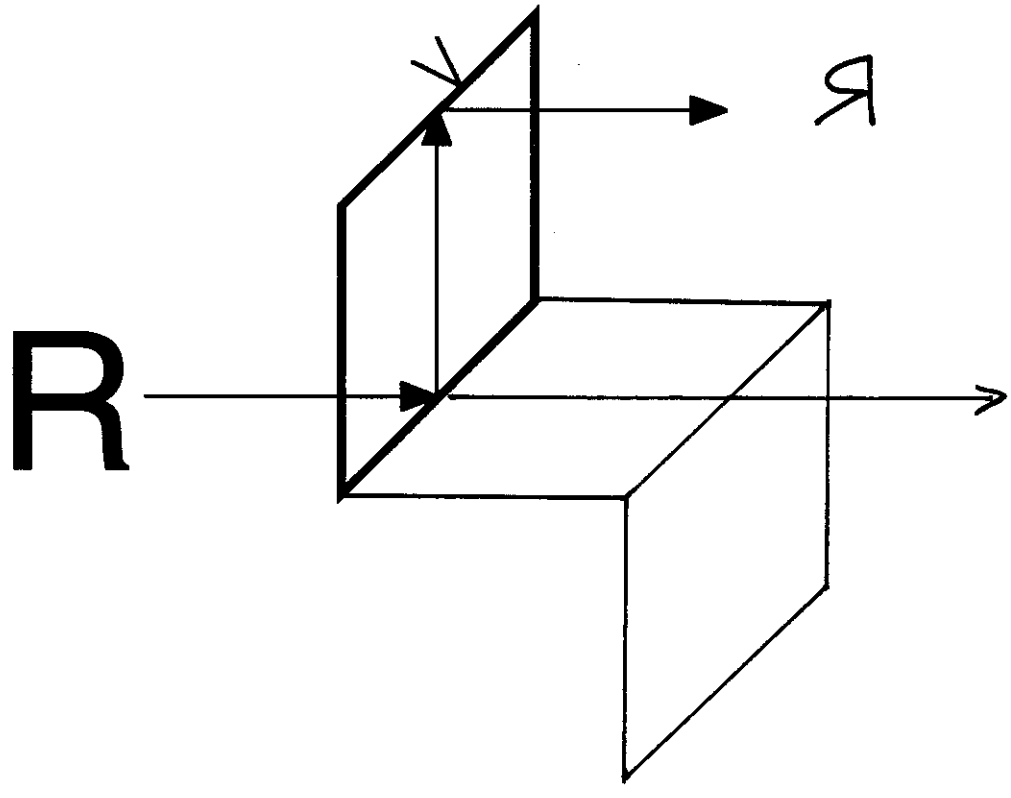
October 18, 1998 Lecture 16 Name Solutions

Closed book; closed notes. Use the back sides if required.
Do not use any pre-stored information or programs in your calculator
Not all of the necessary information may be given for design problems.
Note any assumptions you make in solving the problems. Show your work.

1) (10 points) Draw the tunnel diagram for the prism and ray path shown.
Note that one of the surfaces has a roof.

What is the resulting image parity and orientation? Looking back through the prism, sketch the image of the R.

3 reflections: - left handed
- reverted



2) (20 points) Do a paraxial ray trace of the following cemented doublet lens in air to determine the system power and the location of the *rear* principal plane and focal point. Give the locations relative to the rear vertex.

R1 = -200 mm	t1 = 5.0	n1 = 1.7408
R2 = 100 mm	t2 = 5.0	n2 = 1.5001
R3 = 250 mm		

A spare raytrace sheet can be found on the last page of this exam.

$\phi_i = \alpha_n / R$

Trace an object ray from infinity

	1	2	3	4	
R	-200	100	250		
t	∞	5.0	5.0	?	
n	1.0	1.7408	1.5001	1.0	
$-\phi$	.003704	.002407	.002000		
z	∞	2.8722	3.3331	BFD	
y	1	1	1.0106	1.0311	0
w	0	.003704	.006137	.008199	
u					

$$\phi = -\frac{w_k}{y_1} = -.008199$$

$$\phi = -.008199 \text{ /mm}$$

$$f_e = 1/\phi = -121.97 \text{ mm}$$

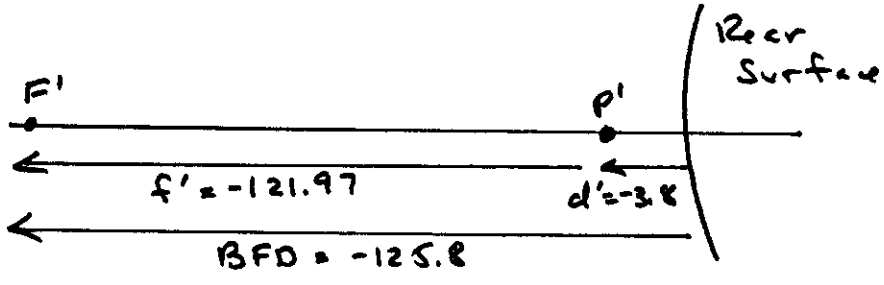
$$f' = f_e = -121.97 \text{ mm}$$

$$.008199 \cdot BFD + 1.0311 = 0$$

$$BFD = -125.8$$

$$BFD = f' + d'$$

$$d' = -3.8 \text{ mm}$$



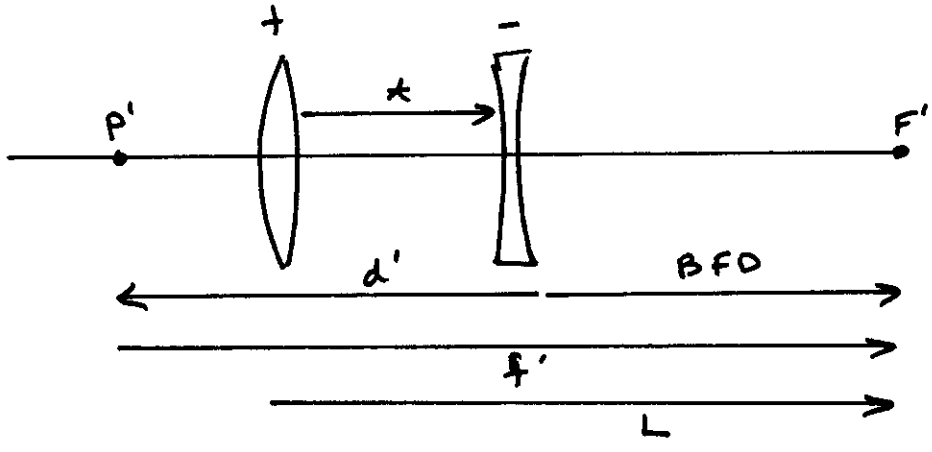
3) (20 points) Do a first order design of a telephoto lens (two thin lenses) with the following specifications. Provide the required element focal lengths and spacings.

Focal length:	200 mm
Back Focal Distance:	75 mm
Telephoto Ratio*:	0.75

$\phi = 1/f = .005$

*The Telephoto ratio is the ratio of the system length (front element to image plane) to the system focal length.

Telephoto:



Telephoto Ratio = 0.75 = $L/f = \frac{t + BFD}{f} = \frac{t + 75}{200}$ $\quad t = 75$ mm

$BFD = f' + d' \qquad d' = BFD - f' = 75 - 200 \qquad d' = -125$ mm

$d' = -125\text{mm} = -\phi_1/\phi\, t = \frac{-\phi_1\, 75}{.005} \qquad \phi_1 = .008333$

$f_1 = 120$ mm

$\phi = \phi_1 + \phi_2 - \phi_1 \phi_2 t$

$\phi_2 = \frac{\phi - \phi_1}{1 - \phi_1 t} = \frac{.005 - .008333}{1 - .008333 \cdot 75} \qquad \phi_2 = -.008888$

$f_2 = -112.5$ mm

$f_1 = 120$ mm

$f_2 = -112.5$ mm $\qquad t = 75$ mm

4) (25 points) You are given a two-element lens system (thin lenses) with the following specifications:

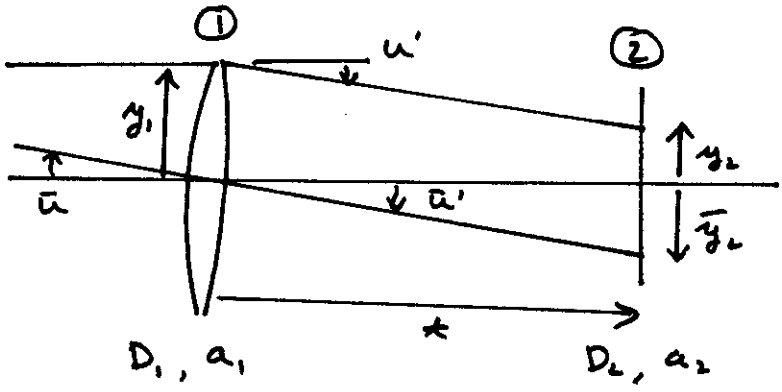
System Focal Length:	400 mm
Front Element Focal Length:	250 mm
Element Separation:	100 mm
F/#:	f/4
Stop Location:	First Element
Unvignetted Field of View:	+/- 10 deg

$\phi_1 = .004$

Determine the required element diameters for both lens elements.

$f/\# = \dfrac{f_e}{D_{EP}}$ $\quad D_{EP} = 100\,mm$ $\quad$ EP at Lens 1

$D_1 = 100\,mm$; $a_1 = 50\,mm$



$y_1 = a_1 = 50\,mm$

$\bar{u} = -\tan 10°$

$\bar{u}' = \bar{u} = -.1763$

Need the marginal and chief ray heights at Lens (2):

Marginal: $u' = u - y_1\phi_1 = -y_1\phi_1 = -50(.004) = -.2$

$y_2 = y_1 + u't = 50 - .2(100) = \underline{30\,mm}$

Chief: $\bar{y}_2 = \bar{u}'t = -.1763(100) = \underline{-17.63\,mm}$

Element 2: No Vignetting $\quad a_2 = |y_2| + |\bar{y}_2| = 47.63\,mm$

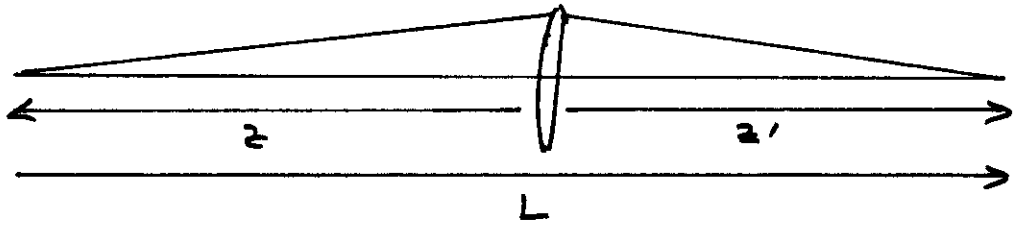
Element 1:

$$D_2 = 95.27\,mm$$

$$D_1 = 100\,mm$$

No need to determine f_2.

5) (10 points) You are designing an optical system with a requirement of an overall object-to-image distance of 250 mm and an image magnification of -1/9. Assuming a single thin lens, determine the required focal length and lens position.



$m = z'/z = -1/9 \qquad z = -9z'$

$L = z' - z = 10z' = 250 \text{ mm}$

$z' = 25 \text{ mm}$

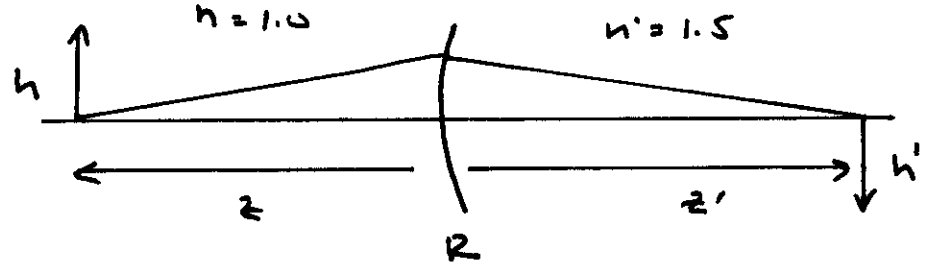
$z = -225 \text{ mm}$

$\frac{1}{z'} = \frac{1}{z} + \frac{1}{f}$

$\frac{1}{f} = \frac{1}{25} + \frac{1}{225}$

$f = 22.5 \text{ mm}$

6) (15 points) An object 10 mm high is located 200 mm to the left of a single refracting convex surface of radius 50 mm. The object is in air, and the image space index is 1.5 Where is the image, and how big is it?



$h = 10$ mm $\quad R = 50$ mm $\quad \phi = (n'-n)/R$

$z = -200$ mm $\quad \phi = .01/\text{mm}$

$f_e = 100$ mm

$$\frac{n'}{z'} = \frac{n}{z} + \frac{1}{\phi} = \frac{-1}{200} + .01 = .005$$

$$z'/n' = 200 \text{ mm}$$

$$z' = \underline{300 \text{ mm}}$$

$$m = \frac{z'/n'}{z/n} = -1 \qquad h' = -h = \underline{-10 \text{ mm}}$$

We could also note that this is a 1:1 system:

Object at 2f ; Image at 2f'

or $\quad -z/n = z'/n' = 2f_e$