

October 12, 2004 Lecture 15

Name Solutions

Closed book; closed notes. An equation sheet is attached and can be removed.

Use the back sides if required.

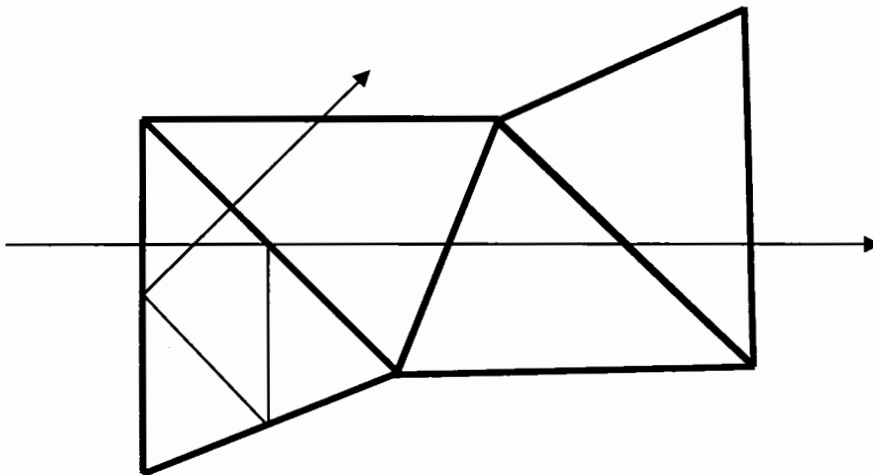
Do not use any pre-stored information or programs in your calculator.

Note any assumptions you make in solving the problems.

Show your work. Present it in a neat and logical fashion.

Distance Students: Please return the original exam only; do not FAX an additional copy.

1) (10 points) Draw the tunnel diagram for this prism and the ray path shown.



2) (15 points) You are taking a picture of a 6 foot tall person standing 18 feet away from you. The dimensions of the sensor in your camera are 10 mm x 10 mm.

a) Approximately what focal length lens do you need to fit the image of the person onto the sensor?

$$6' = 1829 \text{ mm} = h$$

$$18' = 5486 \text{ mm} = -z$$

$$h' = -10 \text{ mm (inverted)}$$

$$m = \frac{h'}{h} = -.0055$$

$$f \approx z' \quad m = \frac{z'}{z} \approx \frac{f}{z}$$

$$f \approx m z = -.0055 (-5486 \text{ mm})$$

$$\underline{f \approx 30 \text{ mm}}$$

b) You now want to switch lenses so you can take a "head and shoulders" shot of the person. Approximately what focal length lens should you use?

$$\text{For this shot } h \approx 1.5' = 457 \text{ mm}$$

$$m = -.022$$

$$\underline{f \approx 120 \text{ mm}}$$

or the object size is $\frac{1}{4}$ that of part (a). The required magnification increases by a factor of 4, as does the focal length.

3) (30 points) Use Gaussian reduction to determine the back focal distance of the following three surface optical system:

$$n = n_0 = 1.33 \quad R_1 = 25.0$$

$$n_1 = 1.50 \\ t_1 = 5.0 \quad R_2 = -40.0$$

$$n_2 = 1.60 \\ t_2 = 5.0 \quad R_3 = -60.0$$

$$n' = n_3 = 1.33$$

Note: Solutions obtained using raytrace methods will receive zero credit.

$$\phi_i = (n_i' - n_i) C_i = (n_i' - n_i) / R_i$$

$$\phi_1 = (1.50 - 1.33) / 25.0 = .0068$$

$$\tau_i = t_i / n_i$$

$$\phi_2 = (1.60 - 1.50) / -40.0 = -.0025$$

$$\tau_1 = 5.0 / 1.50 = 3.33$$

$$\phi_3 = (1.33 - 1.60) / -60.0 = .0045$$

$$\tau_2 = 5.0 / 1.60 = 3.125$$

Reduce the first two surfaces:

$$\phi_{12} = \phi_1 + \phi_2 - \phi_1 \phi_2 \tau_1$$

$$\phi_{12} = .004357$$

$$\delta'_{12} = \frac{d_{12}}{n_2} = - \frac{\phi_1}{\phi_{12}} \tau_1 = -5.202$$

Reduced spacing for the third surface:

$$\tau = \tau_2 - \delta'_{12} = 8.327$$

continues.....

Reduce with the third surface:

$$\phi = \phi_1 + \phi_3 - \phi_1 \phi_3 r$$

$$\phi = .00869$$

$$f_E = 1/\phi = 115.0$$

$$f_E' = n' f_E = 153.0$$

$$s' = \frac{d'}{n'} = - \frac{\phi_1}{\phi} r = -4.168$$

$$d' = -5.544$$

$$\text{BFD} = f_E' + d' = 147.5$$

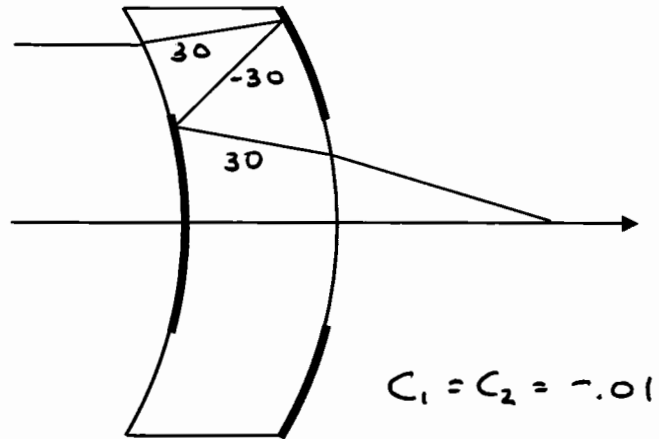
4) (30 points) A catadioptric system uses both reflection and refraction to achieve its focal power. A solid catadioptric system (a solid-cat) can be produced by coating portions of the front and rear surfaces of a lens so that there are transmissive and reflective zones on each surface. In this system, both surfaces have the same radius of curvature.

$R_1 = R_2 = -100 \text{ mm}$

$t = 30$

$n = 1.5$

The system is in air



Use a paraxial raytrace to determine the back focal distance and the system focal length.

Surface	0	Front 1	Rear 2	Front 3	Rear 4	F'	5	6
C		-.01	-.01	-.01	-.01	-		
t	∞	30	-30	30	BFD			
n	1.0	1.5	-1.5	1.5	1.0			
$-\phi$.005	-.03	.03	-.005	-		
t/n	∞	20	20	20	22.82			
Ray parallel to the axis:								
y	1.0	1.0	1.10	.540	.304	0		
nu	0	.005	-.028	-.0118	-.01332			
u		.00333	.01867	-.00787				
y								
nu								
u								

BFD = 22.82 mm

$\phi = -\frac{u'}{y_i} = .01332/\text{mm}$

$f_E = 1/\phi = 75.08 \text{ mm}$

5) (15 points) A cemented doublet is a lens assembly with two glass elements glued together. The glued surfaces have the same radius of curvature (one concave and one convex).

How does the power of this lens assembly depend on the index of refraction of the very thin glue layer? Prove your result.

First, consider the power of a Glass-Glass interface:

$$(n_1 \rightarrow n_2)$$

$$\phi_{G-G} = (n_2 - n_1) C$$

Now, reduce a Glass-Glue-Glass interface:

$$(\text{glue} \rightarrow n_g)$$

$$\phi_1 = (n_g - n_1) C$$

$$\phi_2 = (n_2 - n_g) C$$

$$t = t_g / n_g$$

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

$$\phi_g = (n_g - n_1) C + (n_2 - n_g) C - (n_g - n_1)(n_2 - n_g) C^2 t_g / n_g$$

$$\phi_g = (n_2 - n_1) C - (n_g - n_1)(n_2 - n_g) C^2 t_g / n_g$$

If t is small

$$\underline{\phi_g = (n_2 - n_1) C = \phi_{G-G}}$$

The thin glue layer adds no power.

Also, a thin air gap between two surfaces of equal curvature adds no power.