

## Concave-Convex Lens with Embedded Stop

### a) Entrance Pupil

Front Surface:  $\phi_1 = (1.5 - 1.0)/R_1$        $\phi_1 = -0.005/\text{mm}$

EP: Image the stop into object space.

Light going from Right to Left.

$$\frac{n'}{z'_{EP}} = \frac{n}{z_{STOP}} + \phi_1$$

$$z_{STOP} = x_1 = 10 \text{ mm}$$

$$n = -1.5 \quad n' = 1.0$$

- For EP imaging

$$\frac{-1}{z'_{EP}} = \frac{-1.5}{10} - 0.005$$

$$z'_{EP} = 6.45 \text{ mm}$$

to the Right of  $V_1$

$$m_{EP} = \frac{z'_{EP}/n'}{z_{STOP}/n} = \frac{-6.45}{10/-1.5}$$

$$m_{EP} = 0.968$$

$$D_{EP} = m_{EP} D_{STOP} = 19.35 \text{ mm}$$

## b) Focal Length and Exit Pupil

A potential chief ray must be traced from the stop to the XP.

Surface	Obj	R1	Stop	R2	XP	F'	
0	1	2	3	4	5	6	
$R$		-100	-	-50			
$t$	$\rightarrow$	10	15	$z'_{XP}$	$z'_{XP \rightarrow F'}$		
$n$		1.0	1.5	1.5	1.0	1.0	
$-\phi$		0.005	-	-0.01	-	-	
$t/n$	$\rightarrow$	6.667	10.0	$z'_{XP}$	$z'_{XP \rightarrow F'}$		
Potential Chief Ray - zero at Stop and XP							
$\bar{y}$			0	1.0	0		
$n\bar{u}$		0.1	0.15	0.09			
$u$							
Potential Marginal Ray							
$\tilde{y}$	1	1	1.0333	1.0833	1.148	0	
$n\tilde{u}$	0	0.005	0.005	-0.005833	-0.005833		
$u$							
Marginal Ray: Scale to Stop Radius $r_{STOP}/r_{XP} = 10/1.0333 = 9.678$							
$y$	9.678	9.678	10.0	10.48	11.11	0	
$nu$	0	.0484	.0484	-.0565	-.0565		
$u$							

$$z'_{XP} = -11.11$$

$$z'_{XP \rightarrow F'} = 196.8$$

$$n'u' = -0.565 \quad \bar{y}_1 = 9.678$$

$$n'\tilde{u}' = -0.005833 \quad \tilde{y}_1 = 1.0$$

$$y_{XP} = 11.11$$

$$D_{xp} = 2 r_{xp} = 22.22 \text{ mm}$$

$$r_{xp} = 8 r_{xp} = 11.11 \text{ mm}$$

$$x_p : \quad z'_{xp} = -11.11 \quad (\text{to the left of } V_2)$$

$$BFD = 185.7 \text{ mm}$$

$$BFD = z'_{xp} + z'_{xp} + 196.8 \text{ mm} - (11.11 \text{ mm})$$

$$f = \frac{1}{\phi} = 171.4 \text{ mm}$$

$$\phi = - \frac{z'_1}{n'_1 u'_1} = - \frac{z'_1}{n'_1 u'_1} = .005833/\text{mm}$$