Peephole

Eye: $r = 5.65$ mm $\qquad n = 1.333$

$$\phi = (n-1)\,C = .0590/\text{mm}$$

$$f_e = 16.95 \text{ mm}$$

$$f' = n\,f_e = 22.6 \text{ mm}$$

Macula: 3 mm Dia

Image size limit = 1.5 × Macula = 4.5 mm Dia

Chief ray angles at cornea

$$\bar{u}' = 2.25 \text{ mm}/f' = .100$$

$$\bar{u} = n\,\bar{u}' = 2.25 \text{ mm}/f_e = .133$$

FOV of the eye

$$\text{FOV} = 2 \tan^{-1}(\bar{u}) = 15.2^\circ$$

(Central High-Resolution Zone)

a)

Telescope Requirements

$$\text{FOV} = 90^\circ \quad (\text{Full Field})$$

Chief ray angle in object space (paraxial angle)

$$\bar{u}_o = \tan(\text{FOV}/2) = 1.00$$

Required $MP = \bar{u}/\bar{u}_0 = .133/1.00 = .133$

$$\boxed{m = 1/MP = 7.52}$$

- Remember that m and MP are paraxial quantities, and we must use the values of $\bar{u}$, not FOV.

This requires a reducing telescope that will make the scene appear farther away to increase the FOV.

<u>Telescope Design</u> - non inverting

Use a reversed Galilean (neg in front)

$t = f_1 + f_2$ $\qquad\qquad m = -f_2/f_1$

$$f_2 = -m f_1$$

$$t = f_1 - m f_1 = (1-m) f_1$$

$$f_1 = t/(1-m)$$

$t = 25\text{mm}$ $\qquad m = 7.52$

$f_1 = -3.83 \text{ mm}$ $\qquad \phi_1 = -.261/\text{mm}$

$f_2 = 28.83 \text{ mm}$ $\qquad \phi_2 = .0347/\text{mm}$

$t = 25\text{mm}$

b) For vignetting, we need the marginal and chief ray values at both lenses.

The marginal ray is easy since the telescope is afocal and the object is at infinity. The marginal ray is parallel to the axis between L2 and the eye.

$$y(L2) = y(\text{cornea}) = 2\ \text{mm}$$

$$y(L1) = y(L2)/m = .266\ \text{mm}$$

The chief ray values can be found by starting at the cornea: $\bar{y}(c) = 0$

$$\bar{u}(c) = .133$$

Backward ray trace $t_2 = 25$ mm

$$\bar{y}(L2) = \bar{y}(c) - \bar{u}(c)\,t_1$$

$$\longrightarrow \quad \bar{y}(L2) = -3.32$$

$$\bar{u}(L2) = \bar{u}'(L2) + \bar{y}(L2)\,\phi(L2)$$

$\bar{u}'(L2) = \bar{u}(c)$

$$\bar{u}(L2) = .0178$$

$t_1 = 25$

$$\bar{y}(L1) = \bar{y}(L2) - \bar{u}(L2)\,t_2$$

$$\longrightarrow \quad \bar{y}(L1) = -3.77$$

These results also produce $\bar{u} = 1.00$ in object space.

For a totilly vignetted field:

$a \le |\bar{y}| - |y|$ and $a \ge |y|$

L1:

$a_1 \le |-3.77| - |.266|$ and $a_1 \ge |.266|$

$a_1 \le 3.50$ mm and $a > .266$

$$\boxed{\begin{aligned} a_1 &= 3.50 \text{ mm} \\ D_1 &= 7.00 \text{ mm} \end{aligned}}$$

L2:

$a_2 \le |3.32| - |2.00|$ and $a_2 \ge |2.00|$

$a_2 \le 1.32$ and $a \ge 2.00$

Here, we must use the second condition since we do not want the second lens to become the system stop. The fully vignetted field is therefore not limited by the second lens.

$$\boxed{\begin{aligned} a_2 &= 2.00 \text{ mm} \\ D_2 &= 4.00 \text{ mm} \end{aligned}}$$

c) Retinal Illuminance —

Scene: $E_v = .27\ lm/m^2$ $\rho = .18$

$$L_v = \rho E_v / \pi = .0155\ lm/m^2\ sr$$

To get the retinal illuminance, there are several approaches. We must include the index of the eye (1.333)

Basic Luminance is conserved

$$L_R/n^2 = L_v$$

$$L_R = n^2 L_v$$

and we multiply by the solid angle of the iris to get the illuminance

$$\Omega = \frac{\pi D^2/4}{f'^2} \qquad E_R = L_R \Omega$$

rear focal length

$$E_R = \frac{\pi n^2 L_v}{4 f'^2/D^2} \qquad f_e = f'/n$$

effective focal length

$$E_R = \frac{\pi L_v}{4 f_e^2/D^2} = \frac{\pi L_v}{4 (f/\#)^2} \qquad f/\# = f_e/D$$

This is the basic camera equation – remember that n is hidden in $f/\#$ since it is defined in terms of f_e not f'

$$E_R = .00068\ lm/m^2 = .00068\ lx$$