Homework 11 Solutions

1. Image Quality (F15 Final Q7)

A 200mm x 300mm monochrome monitor is to be viewed at a distance of 500mm. It's desired that the image quality match the resolution of the eye (angular resolution of the eye $1\ arc\ \min = \frac{1}{60} degrees$). The image was captured on a 10mm x 15mm detector.

The camera is designed using the hyperfocal condition so that objects between 2m and infinity meet the above image quality or blur condition.

a. What is the approximate resolution of the system in pixels (assume the blur size equals the pixel size)?

Blur on monitor

$$B_M = \tan(resolution\ of\ the\ eye) \cdot viewing\ distance$$

$$B_M = \tan\left(\frac{1}{60}\right) \cdot 500mm = 0.145mm$$

Blur on detector

Magnification from detector to monitor

$$m = \frac{200mm}{10mm} = 20.0 \ \ (or\ m = \frac{300mm}{15mm} = 20.0)$$

$$B_D' = \frac{B_M}{m} = 0.00727mm$$

Pixel count

First assume that $B_D' = pixel\ size$

Height: $\frac{15mm}{0.00727mm} = 2062.6 \rightarrow 2063\ pixels$

Width: $\frac{10mm}{0.00727} = 1375.1 \rightarrow 1376\ pixels$

Resolution: $1376\ x\ 2063\ pixels$

b. What is the required $f/\#$ for the imaging lens given that the focal length of the lens is approximately 15.8mm?

Hyperfocal distance $L_{near} = -2m$

$$L_H = 2 \cdot L_{near} = -4m = -4000mm$$

$$L_H = -\frac{fD}{B_D'} = -\frac{f^2}{(f/\#)B_D'} = -4000$$

$$f/\# = \frac{f^2}{4000 \cdot B_D'} = 8.6$$

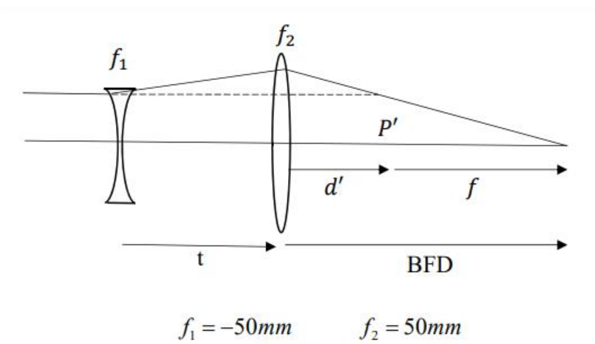
2. Reverse Telephoto Zoom Lens

Design a two-element reverse telephoto zoom lens:

Focal length ranges	30-80mm
Lens configuration	Two-element zoom lens
	Reverse-telephoto configuration (negative-positive)
Element focal lengths	$f_1 = -50mm,\ f_2 = +50mm$

Assume an object at infinity. Both elements are thin lenses in air.

a. Provide the equations for the element separation and the back focal distance as a function of the system focal length.



$f = 30 \rightarrow 80mm$

$\varphi = \varphi_1 + \varphi_2 - \varphi_1\varphi_2 t$

$\varphi_1 = -\varphi_2 = -\dfrac{1}{50mm} =$

$\dfrac{1}{f} = \varphi_1 - \varphi_1 + \varphi_1^2 t \rightarrow f = \dfrac{1}{\varphi_1^2 t} = \dfrac{f_1^2}{t} \rightarrow t = \dfrac{f_1^2}{f}$

$$BFD = f + d'$$

$$d' = -\frac{\varphi_1}{\varphi}t = -\frac{f_1^2}{t}\cdot\frac{1}{f_1}t = -f_1 = 50mm$$

$$BFD = f + 50mm$$

$$L = t + BFD = \frac{2500mm^2}{f} + f + 50mm$$

b. Plot the lens positions as a function of the system focal length (between 30mm and 80mm with at least a 10mm interval).

f	$t = \frac{f_1^2}{f}$	$BFD = f + 50mm$	$L = t + BFD$
30.00mm	83.33mm	80.00mm	163.33mm
40.00mm	62.50mm	90.00mm	152.50mm
50.00mm	50.00mm	100.00mm	150.00mm
60.00mm	41.67mm	110.00mm	151.67mm
70.00mm	35.71mm	120.00mm	155.71mm
80.00mm	31.25mm	130.00mm	161.25mm

f	t	BFD	L
30	83.3333	80	163.333
40	62.5	90	152.5
50	50	100	150
60	41.6667	110	151.667
70	35.7143	120	155.714
80	31.25	130	161.25

lens 1	lens 2	f
-163.333	-80	30
-152.5	-90	40
-150	-100	50
-151.667	-110	60
-155.714	-120	70
-161.25	-130	80