Engineering Optics, Term Project

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1 Image-side focus point and focus length of the camera lens

For the Camera lens 1, the structure parameters are as follows:

Surface	**Radius**	**Thickness**	**Glass**
diaphragm	46.839	3.17	n=1.51633, v=64.15
2	860.1441	0.1	
3	26.221	6.85	n=1.51633, v=64.15
4	57.871	2.28	
5	124.006	14	n=1.74073, v=27.97
6	18.626	11.19	
7	43.776	2.42	n=1.761441, v=26.55
8	121.402	51.27	

Table 1: Structure parameters for Camera lens 1

And we have the initial conditions:

$$
\begin{aligned}
l_1 &= -\infty \\
h_1 &= 1mm \\
i_1 &= \frac{h_1}{r_1} = \frac{1}{46.839} = 0.0213497 \\
n_0 &= 1
\end{aligned}
$$

Filling the table with the formulas

$$l_{k+1} = l'_k - d_k \tag{1}$$

$$i_k = \frac{(l_k - r_k) \cdot u_k}{r_k} \tag{2}$$

$$i'_k = \frac{n_{k-1} \cdot i_k}{n_k} \tag{3}$$

$$u'_k = u_k + i_k - i'_k \tag{4}$$

$$l'_k = r_k \cdot (1 + \frac{i'_k}{u'_k}) \tag{5}$$

Index	l	i	i′	u′	l′
1	$-\infty$	0.021350	0.014080	0.007270	137.554240
2	134.384240	-0.006134	-0.009301	0.010437	93.604411
3	93.504411	0.026782	0.017662	0.019557	49.902009
4	43.052009	-0.005008	-0.007594	0.022142	38.024545
5	35.744545	-0.015760	-0.009054	0.015436	51.273891
6	37.273891	0.015454	0.026901	0.003989	144.249128
7	133.059128	0.008135	0.004618	0.007505	70.713667
8	68.293667	-0.003283	-0.005783	0.010005	51.229261

Table 2: Descriptive caption for the table

Based on the above calculations, we have:

$$l'_8 = 51.229261$$
$$u'_8 = 0.010005$$

So we can know $\mathbf{l'_F = 51.229261mm}$, the image-side focus point is placed **51.229261mm** behind the last surface of the lens group.
And we can calculate the focus length f:

$$\boxed{f' = \frac{h}{u'} = \frac{1}{0.010005} = 99.950025\mathbf{mm}}$$

Therefore, the vertex of the lens group is placed **99.950025mm** away from the image-side focus point. That is, the vertex is place **48.720764mm** away behind the last surface of the lens group.

2 Object-side vertex and focus point

Because of the reversibility of the light path, we can reverse the lengs group. so the structure is as follows:

Surface	Radius	Thickness	Glass
1	121.402	51.27	n=1.761441, v=26.55
2	43.776	2.42	
3	18.626	11.19	n=1.74073, v=27.97
4	124.006	14	
5	57.871	2.28	n=1.51633, v=64.15
6	26.221	6.85	
7	860.1441	0.1	n=1.51633, v=64.15
diaphragm	46.839	3.17	

Table 3: Reordered structure parameters for Camera lens 1

We can use the same initial conditions:

$$l_1 = -\infty$$
$$h_1 = 1mm$$
$$i_1 = \frac{h_1}{r_1} = \frac{1}{121.402} = 0.008240$$
$$n_0 = 1$$

Filling the table with the same formulas, we have

Index	l	i	i′	u′	l′
1	$-\infty$	0.002135	0.001212	0.000923	280.839172
2	229.569172	0.003917	0.006900	-0.002060	-102.867777
3	-105.287777	0.013702	0.007872	0.003771	57.505206
4	46.315206	-0.002363	-0.004113	0.005521	31.634481
5	17.634481	-0.003839	-0.002532	0.004214	23.104513
6	20.824513	-0.000867	-0.001315	0.004662	18.824167
7	11.974167	-0.004597	-0.003032	0.003096	18.027212
8	17.927212	-0.001911	-0.002898	0.004083	13.594514

Table 4: Detailed data for the optical characteristics over different indices

Based on the above calculations, we have:

$$l'_8 = 13.594514$$
$$u'_8 = 0.004083$$

That means, the object-side vertex is placed **13.594514mm** in front of the first surface of the lens group. and we have the object-side focus length:

$$\boxed{f = -\frac{h}{u'} = \frac{1}{0.004083} = -244.999268\mathbf{mm}}$$

Therefore, the object-side focus point is placed **244.999268mm** in front of the object-side vertex. the vertex is placed **231.404754mm** in front of the first surface of the lens group.

3 Imaging calculations

the child is placed $d_1 = -x_1 - f = 9000mm, d_2 = -x_2 - f = 10000mm$ in front of the first surface of the lens group. The height of the child is $h_1 = 0.8 \times 10^3 mm$.
we can calculate the x'_1 and the x'_2 by the Newton Formula:

$$x'_k = \frac{f \cdot f'}{x_k} = \frac{f \cdot f'}{f - d_k} \tag{6}$$

Therefore, we have:

$$x'_1 = \frac{99.950025 \cdot (-244.999268)}{99.950025 - 9000} = 2.75141\mathbf{mm}$$
$$x'_2 = \frac{99.950025 \cdot (-244.999268)}{99.950025 - 10000} = 2.47349\mathbf{mm}$$

So the image height of the child is:

$$h'_1 = -\frac{x'}{f'} = -\frac{2.75141}{99.950025} = -0.02753\mathbf{mm}$$
$$h'_2 = -\frac{x'}{f'} = -\frac{2.47349}{99.950025} = -0.02474\mathbf{mm}$$