Engineering Optics, Homework 4

He Tianyang

April 3, 2024

1 Problem 1

Chapter 4, Problem 1

In this case, the negative file is the field diaphragm, with a size 55×55**mm** and with the focus length 75**mm**. Therefore, we have

$$\boxed{\Phi = 2 \cdot \arctan \frac{55 \cdot \sqrt{2}}{2 \cdot 75} \approx 54.82°} \tag{1}$$

2 Problem 2

Chapter 4, Problem 3

Given the following parameters for the binoculars:

- Objective lens diameter $D = 30\,mm$
- Objective lens focal length $f_o = 108\,mm$
- Eyepiece focal length $f_e = 18\,mm$
- Exit pupil distance $\geq 11\,mm$
- Exit pupil diameter $= 5\,mm$
- Eyepiece clear aperture $= 20\,mm$
- Without field stop

The formula for the field of view (FoV) is given by:

$$\text{FoV} = 2 \cdot \tan^{-1}\left(\frac{D}{2f_o}\right)$$

Substituting the given values:

$$\text{FoV}_{\text{max}} = 2 \cdot \tan^{-1}\left(\frac{30}{2 \cdot 108}\right)$$

This yields:

$$\boxed{\text{FoV}_{\text{max}} \approx 15.81°}$$

Considering the vignetting coefficient k, the effective diameter is halved. Using this in the formula:

$$\mathrm{FoV}_k = 2 \cdot \tan^{-1}\left(\frac{k \cdot D}{2 f_o}\right)$$

Substituting $k = 0.5$:

$$\mathrm{FoV}_k = 2 \cdot \tan^{-1}\left(\frac{0.5 \cdot 30}{2 \cdot 108}\right)$$

This gives:

$$\boxed{\mathrm{FoV}_k \approx 7.94^\circ}$$

3 Problem 3

Chapter 4, Problem 4

With the magnification $\beta = -1$, the object is placed at 2 times focus length. Therefore, we have

$$f_1' + (-f) = d \tag{2}$$

Therefore, we can calculated that

$$f_1' = 36.7mm$$

4 Problem 4

Example 4 -5

4.1 question 1

According to the problem, we have the magnification $\beta = -4$, and $(-l) + l' = 180$
That is,

$$l = -36mm \tag{3}$$
$$l' = 144mm \tag{4}$$

Therefore, using the lens formula, we have

$$\frac{1}{f'} = \frac{1}{l'} - \frac{1}{l} \tag{5}$$

which gives

$$\boxed{f' = 28.8mm} \tag{6}$$

4.2 question 2

In this case, the objective lens is the aperture diaphragm, Therefore

$$\boxed{D_{Object} = 2 \cdot (-l) \cdot \tan -u = 10.89mm} \tag{7}$$

4.3 question 3

According to

$$\frac{D'}{D_{Object}} = \left|\frac{l'}{l}\right| = \frac{18.6}{100.67} \tag{8}$$

we have

$$\boxed{D' = 10.89 \cdot \frac{18.6}{100.67} = 1.26mm} \tag{9}$$

4.4 question 4

Assume the height of the main Optics is h, then we have

$$|h| = \left|y \cdot \frac{l' - f_2}{l}\right| = 8.93mm \tag{10}$$

And, we have

- When $K = 1$, $D = 19.12mm$
- When $K = 0.5$, $D = 17.86mm$
- When $K = 0$, $D = 16.6mm$

5 Problem 5

1. A stop 8mm in diameter is placed halfway between an extended object and a large-diameter lens of 9cm focal length. The lens projects an image of the object onto a screen 14cm away. What is the diameter of the exit pupil?

The diameter of the stop is given as 0.8 cm (converted from 8 mm to cm). The focal length (f) of the lens is 9 cm, and the distance (v) from the lens to the screen is 14 cm.

Using the lens equation

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}, \tag{11}$$

where u is the object distance from the lens, we can solve for u to find the object distance. Once u is found, the magnification (M) of the system can be calculated using

$$M = -\frac{v}{u}. \tag{12}$$

The diameter of the exit pupil (D_{exit}) is then determined by scaling the diameter of the stop (D_{stop}) by the absolute value of the magnification,

$$D_{exit} = D_{stop} \cdot |M|. \tag{13}$$

After solving these equations, we find the diameter of the exit pupil to be **2.04 cm**.

6 Problem 6

2. Two lenses, a lens of 12.5cm focal length and a minus lens of unknown power, are mounted coaxially and 8 cm apart. The system is afocal, that is light entering the system parallel at one side emerges parallel at the other. If a stop 15mm in diameter is placed halfway between the lenses:

- Where is the entrance pupil?

- Where is the exit pupil?
- What are their diameters?

Given:

- Focal length of the first lens (f_1) = 12.5 cm
- Distance between the lenses (d) = 8 cm
- Diameter of the stop = 15 mm = 1.5 cm

Since the system is afocal, the effective focal length of the system is infinity. The formula for the effective focal length of two lenses separated by distance d is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} \tag{14}$$

where $F = \infty$ for an afocal system, thus $\frac{1}{F} = 0$.

Solving for f_2, we find $f_2 = -4.5$ cm, indicating that the second lens is a diverging lens with a focal length of -4.5 cm.

Since the stop is located exactly halfway between the two lenses, and given the afocal nature of the system:

- The entrance pupil is located 4 cm from the first lens.
- The exit pupil is located 4 cm from the second lens.
- The diameters of both the entrance and exit pupils are equal to the diameter of the stop, which is 1.5 cm.