

1. 画图易知

2.

$$f' = 75mm$$

$$x = -\infty, x' = 0mm$$

$$x = -10000mm, x' = 0.5625mm$$

$$x = -8000mm, x' = 0.703125mm$$

$$x = -6000mm, x' = 0.9375mm$$

$$x = -4000mm, x' = 1.40625mm$$

$$x = -2000mm, x' = 2.8125mm$$

3.

$$\beta = -10 = -\frac{fl'}{f'l} = \frac{l'}{l}$$

$$-l + l' + d = 7200mm, -f + f' + d = 1140mm$$

$$\frac{1}{l'} - \frac{1}{l} = \frac{1}{f'}, -f = f'$$

解得 $l = -660mm, l' = 6600mm, f = -600mm, f' = 600mm, d = -60mm$

4.

$$\beta_1 = -3 = \frac{l'_1}{l_1}$$

$$\beta_2 = -4 = \frac{l'_2}{l_2}$$

$$\frac{1}{l'_1} - \frac{1}{l_1} = \frac{1}{f'}$$

$$\frac{1}{l'_2} - \frac{1}{l_2} = \frac{1}{f'}$$

$$l_2 = l_1 + 18mm$$

解得 $l_1 = -288mm, l_2 = -270mm, l'_1 = -864mm, l'_2 = -1080mm, f' = 216mm$

5.

$$\beta_1 = -1 = \frac{l'_1}{l_1}, \frac{1}{l'_1} - \frac{1}{l_1} = \frac{1}{f'_1}$$

$$\beta_2 = -\frac{3}{4} = \frac{l'_2}{l_2}, \frac{1}{l'_2} - \frac{1}{l_2} = \frac{1}{f'_2}$$

$$l' = l'_1 - 20mm, \frac{1}{f'} = \frac{1}{f'_1} + \frac{1}{f'_2}$$

$$f'_1 = 40mm, f'_2 = 240mm$$

6.

$$\beta_1 = -\frac{1}{2} = \frac{l'_1}{l_1}$$

$$\frac{1}{l'_1} - \frac{1}{l_1} = \frac{1}{f'}$$

$$\beta_2 = -1 = \frac{l'_2}{l_2}$$

$$\frac{1}{l'_2} - \frac{1}{l_2} = \frac{1}{f'}$$

$$l_2 = l_1 + 100\text{mm}$$

解得 $f' = 100\text{mm}$

7.

$$\frac{1}{f'} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2} = 1200\text{mm}$$

$$d + l'_2 = 700\text{mm}$$

$$l'_2 = 400\text{mm}$$

$$d = 300\text{mm}, l_1 = -\infty$$

$$l'_1 = f'_1, l_2 = f'_1 - d$$

$$\frac{1}{l'_2} - \frac{1}{l_2} = \frac{1}{f'_2}$$

解得 $f'_1 = 450\text{mm}, f'_2 = -240\text{mm}$

8. 仅考虑双光组结构

$$\frac{1}{f'} = \frac{1}{f'_1} + \frac{1}{f'_2} - \frac{d}{f'_1 f'_2} = \frac{1}{35\text{mm}}, d = L - l'_k$$

$$h_1 = 100\text{mm}, h_2 = h_1 - d \tan U'_1, \tan U'_1 = \frac{h_1}{f'_1}$$

$$\tan U'_2 = \frac{h_2}{l'_k} = \frac{h_1}{f'}$$

解得 $f'_1 = -35\text{mm}, f'_2 = 25\text{mm}$

9.

$$f_1 = \frac{r_1}{1-n} = 400\text{mm}, f'_1 = \frac{nr_1}{n-1} = -600\text{mm}$$

$$f_2 = \frac{nr_2}{n-1} = -900\text{mm}, f'_2 = \frac{r_2}{1-n} = 600\text{mm}$$

$$\Delta = d - f'_1 + f_2 = -250\text{mm}$$

$$f' = \frac{f'_1 f'_2}{-\Delta} = -1440\text{mm}, \Phi = \frac{1}{f'} = 0.69\text{m}^{-1}$$

$$x'_F = \frac{f_2 f'_2}{-\Delta} = -2160\text{mm}, l'_F = x'_F + f'_2 = -1560\text{mm}$$

$$l'_H = l'_F - f' = -120\text{mm}$$

10.

$$\Delta = d - f'_1 - f_2, f'_1 = 100\text{mm}, f'_2 = 50\text{mm}$$

$$f' = -\frac{f'_1 f'_2}{\Delta} = 100\text{mm}, f_2 = -50\text{mm}$$

$$d = 100\text{mm}$$

11.

$$r_1 = 10\text{mm}, r_2 = -10\text{mm}, n = 1.5, d = 60\text{mm}$$

$$f_1 = \frac{nr_1}{n-1} = 30\text{mm}, f'_2 = \frac{r_2}{1-n} = 20\text{mm}, f_2 = \frac{nr_2}{n-1} = -30\text{mm}$$

$$\Delta = d - f'_1 + f_2 = 0\text{mm}$$

$$f' = -\frac{f'_1 f'_2}{\Delta} = \infty$$

$$l_2 = f'_1 - d = -30\text{mm}$$

$$\frac{1}{l'_2} - \frac{n}{l_2} = \frac{1-n}{r_2}, l'_2 = \infty$$

无焦系统出射光线平行于光轴，焦点和主点在无穷远处。

12. 设镜片厚度为极小 $d \approx 0$

$$\begin{aligned} l'_1 &= \frac{r}{1-n} = 480\text{mm} \\ \frac{2}{r} &= \frac{1}{l'}, \frac{n}{l' + d} = \frac{1}{-80\text{mm}} \\ r &= -240\text{mm}, n = 1.5 \end{aligned}$$

13. 条件一：间隔不变，物距任意，放大率不变

$$\begin{aligned} x_1 x'_1 &= -f_1'^2 \\ -x_2 &= d - x'_1 - f'_1 - f'_2 \\ x_2 x'_2 &= -f_2'^2 \\ \beta &= \beta_1 \beta_2 = \frac{f'_1 f'_2}{x_1 x_2} = \frac{f'_1 f'_2}{(f'_1 + f'_2 - d)x_1 - f_1'^2} = \text{constant} \\ \frac{1}{\beta} &= \frac{(f'_1 + f'_2 - d)x_1 - f_1'^2}{f'_1 f'_2} \\ \frac{d(\frac{1}{\beta})}{dx_1} &= 0 = \frac{f'_1 + f'_2 - d}{f'_1 f'_2} \end{aligned}$$

条件二：间隔变化，物距不变，放大率不变

$$\frac{d(\frac{1}{\beta})}{dd} = 0 = -\frac{x_1}{f'_1 f'_2}$$

14.

$$\begin{aligned} l_1 &= f_1, l'_1 = \infty \\ l_2 &= \infty, l'_2 = f'_2 \\ \Delta &= d - f'_1 - f'_2 \\ \beta &= \beta_1 \beta_2 = \frac{f_1 l'_1}{f'_1 l_1} \frac{f_2 l'_2}{f'_2 l_2} = \frac{l'_1 l'_2}{l_1 l_2} = \frac{f'_2}{-f'_1} \\ f' &= -\frac{f'_1 f'_2}{\Delta} = \frac{f'_1 f'_2}{f'_1 + f'_2 - d} \\ x'_F &= \frac{f_2'^2}{d - f'_1 - f'_2} \end{aligned}$$

15. $r_1 = 120\text{mm}, r_2 = -320\text{mm}, d = 30\text{mm}, n = 1.6$

$$\begin{aligned} f_1 &= \frac{r_1}{1-n} = -200\text{mm}, f'_1 = \frac{nr_1}{n-1} = 320\text{mm}, f_2 = \frac{nr_2}{n-1} = -853.333\text{mm}, f'_2 = \frac{r_2}{1-n} = 533.333\text{mm} \\ \Delta &= d - f'_1 + f_2 = -1143.333\text{mm} \\ f' &= -\frac{f'_1 f'_2}{\Delta} = 149.271\text{mm} = -f \\ x'_F &= -\frac{f_2 f'_2}{\Delta} = -398.056\text{mm}, x_F = \frac{f_1 f'_1}{\Delta} = 55.977\text{mm} \\ l_H &= f_1 + x_F - f = 5.248\text{mm}, l'_H = f'_2 + x'_F - f' = -13.993\text{mm} \end{aligned}$$

$$l_1 = -5000mm, \frac{1}{l'_1 - l'_H} - \frac{1}{l_1 - l_H} = \frac{1}{f'}, l'_1 = 139.867mm$$

轴的位置过像方主点位于像方主面内

16. 同上计算只需改变入射侧的折射率从空气的 1 改为水的 1.33

$$\begin{aligned} f_1 &= \frac{n_1 r_1}{n_1 - n_2} = -591.111mm, f'_1 = \frac{n_2 r_1}{n_2 - n_1} = 711.111mm \\ f_2 &= \frac{n_2 r_2}{n_2 - 1} = -853.333mm, f'_2 = \frac{r_2}{1 - n_2} = 533.333mm \\ \Delta &= d - f'_1 + f_2 = -1534.444mm \\ f' &= -\frac{f'_1 f'_2}{\Delta} = 247.164mm, f = \frac{f_1 f_2}{\Delta} = -328.728mm \\ x'_F &= -\frac{f_2 f'_2}{\Delta} = -296.596mm, x_F = \frac{f_1 f'_1}{\Delta} = 273.940mm \\ l_F &= f_1 + x_F = -317.171mm, l_H = l_F - f = 11.557mm \\ l'_F &= f'_2 + x'_F = 236.737mm, l'_H = l'_F - f' = -10.427mm \\ l_1 &= -5000mm, \frac{f}{l_1 - l_H} + \frac{f'}{l'_1 - l'_H} = 1, l'_1 = 254.088mm \end{aligned}$$

17. 注：这里实际上 f_1 为 f'_1

$$\begin{aligned} h_1 &= f'_1 \tan(U'_1) = 50mm \\ h_2 &= h_1 - d_1 \tan(U'_1) = 45mm, \tan(U'_1) = \tan(U_2) = \frac{h_1}{f'_1} = 0.5 \\ \tan(U'_2) &= \tan(U_3) = \tan(U_2) + \frac{h_2}{f'_2} = 1.4, h_3 = h_2 - d_2 \tan(U'_2) = 31mm \\ \tan(U'_3) &= \tan(U_3) + \frac{h_3}{f'_3} = 0.78, f' = \frac{h_1}{\tan(U'_3)} = 64.102mm \\ l'_F &= \frac{h_3}{\tan(U'_3)} = 39.744mm, l'_H = l'_F - f' - d_1 - d_2 \end{aligned}$$

18. 调焦指物距变化时，移动光组使像点绝对位置不动

$$\begin{aligned} l &= -\infty, l' = f' = 75mm \\ l &= -800mm, l' = \frac{f' l}{f' + l} = 82.759mm, l_m = f' - l' = -7.759mm \end{aligned}$$

19.

$$\begin{aligned} \beta &= 1 = \frac{l'}{l}, l' - l = 0 \\ \beta &= -1 = \frac{l'}{l}, l' - l = 2l', \frac{1}{l'} - \frac{1}{l} = \frac{1}{f'}, 2l' = 4f' \end{aligned}$$

20.

$$\begin{aligned} \Delta &= d - f'_1 + f_2 = -125mm, f' = -\frac{f'_1 f'_2}{\Delta} = 80mm = -f \\ x'_F &= -\frac{f_2 f'_2}{\Delta} = -80mm, x_F = \frac{f_1 f'_1}{\Delta} = 80mm \\ x &= -50 - f_1 - x_F = -30mm, x' = \frac{f f'}{x} = 213.333mm \\ l'_2 &= f'_2 + x'_F + x' = 233.333mm \end{aligned}$$

21. 对无穷远物成实像, $l'_F = x'_F + f'_2 > 0$, 即像方焦点在第二面右侧

$$f' = 1200\text{mm} = -\frac{f'_1 f'_2}{\Delta}, \Delta = 300\text{mm} - f'_1 - f'_2, x'_F = -\frac{f_2 f'_2}{\Delta} = 400 - f'_2$$

解得 $f'_1 = 450\text{mm}, f'_2 = -240\text{mm}$

22.

$$\begin{aligned} l'_1 - l_1 &= 900\text{mm} \\ \frac{1}{l'_1} - \frac{1}{l_1} &= \frac{1}{f'} \\ \frac{1}{l'_1 - l} - \frac{1}{l_1 - l} &= \frac{1}{f'} \\ \beta_1 &= \frac{l'_1}{l_1}, \beta = \frac{l'_1 - l}{l_1 - l} = \frac{\beta_1}{4} \end{aligned}$$

解得 $l_1 = -1800\text{mm}, l'_1 = -900\text{mm}, f' = -1800\text{mm}, l = -2700\text{mm}$ 和 $l_1 = -600\text{mm}, l'_1 = 300\text{mm}, f' = 200\text{mm}, l = -300\text{mm}$ 考虑只成实像, 取后者。