

1. 画图易知

2.

$$f' = 75\text{mm}$$

$$x = -\infty, x' = 0\text{mm}$$

$$x = -10000\text{mm}, x' = 0.5625\text{mm}$$

$$x = -8000\text{mm}, x' = 0.703125\text{mm}$$

$$x = -6000\text{mm}, x' = 0.9375\text{mm}$$

$$x = -4000\text{mm}, x' = 1.40625\text{mm}$$

$$x = -2000\text{mm}, x' = 2.8125\text{mm}$$

3.

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

$$-l + l' + d = 7200\text{mm}, -f + f' + d = 1140\text{mm}$$

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

解得  $l = -660\text{mm}, l' = 6600\text{mm}, f = -600\text{mm}, f' = 600\text{mm}, d = -60\text{mm}$

4.

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

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

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

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

$$l_2 = l_1 + 18\text{mm}$$

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

5.

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

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

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

$$f'_1 = 40\text{mm}, f'_2 = 240\text{mm}$$

6.

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

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

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

$$\frac{1}{l'_2} - \frac{1}{l_2} = \frac{1}{f'} \\ l_2 = l_1 + 100mm$$

解得  $f' = 100mm$

7.

$$\frac{1}{f'} = \frac{1}{f'_1} + \frac{1}{f'_2} - \frac{d}{f'_1 f'_2} = 1200mm \\ d + l'_2 = 700mm$$

$$l'_2 = 400mm$$

$$d = 300mm, l_1 = -\infty$$

$$l'_1 = f'_1, l_2 = f'_1 - d \\ \frac{1}{l'_2} - \frac{1}{l_2} = \frac{1}{f'_2}$$

解得  $f'_1 = 450mm, f'_2 = -240mm$

8. 仅考虑双光组结构

$$\frac{1}{f'} = \frac{1}{f'_1} + \frac{1}{f'_2} - \frac{d}{f'_1 f'_2} = \frac{1}{35mm}, d = L - l'_k \\ h_1 = 100mm, h_2 = h_1 - d \tan U'_1, \tan U'_1 = \frac{h_1}{f'_1} \\ \tan U'_2 = \frac{h_2}{l'_k} = \frac{h_1}{f'}$$

解得  $f'_1 = -35mm, f'_2 = 25mm$

9.

$$f_1 = \frac{r_1}{1-n} = 400mm, f'_1 = \frac{nr_1}{n-1} = -600mm \\ f_2 = \frac{nr_2}{n-1} = -900mm, f'_2 = \frac{r_2}{1-n} = 600mm \\ \Delta = d - f'_1 + f_2 = -250mm \\ f' = \frac{f'_1 f'_2}{-\Delta} = -1440mm, \Phi = \frac{1}{f'} = 0.69m^{-1} \\ x'_F = \frac{f_2 f'_2}{-\Delta} = -2160mm, l'_F = x'_F + f'_2 = -1560mm \\ l'_H = l'_F - f' = -120mm$$

10.

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

11.

$$r_1 = 10mm, r_2 = -10mm, n = 1.5, d = 60mm \\ f'_1 = \frac{nr_1}{n-1} = 30mm, f'_2 = \frac{r_2}{1-n} = 20mm, f_2 = \frac{nr_2}{n-1} = -30mm \\ \Delta = d - f'_1 + f_2 = 0mm \\ f' = -\frac{f'_1 f'_2}{\Delta} = \infty \\ l_2 = f'_1 - d = -30mm$$

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

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

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

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

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

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

17. 注：这里实际上  $f_1$  为  $f'_1$

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

18. 调焦指物距变化时，移动光组使像点绝对位置不动

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

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.

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

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.

$$l'_1 - l_1 = 900\text{mm}$$

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

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

$$\beta_1 = \frac{l'_1}{l_1}, \beta = \frac{l'_1 - l}{l_1 - l} = \frac{\beta_1}{4}$$

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。