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.

$$\beta_1 = -1 = \frac{l'_1}{l}, \frac{1}{l'_1} - \frac{1}{l} = \frac{1}{f'_1}$$
$$\beta_2 = -\frac{3}{4} = \frac{l'}{l}, \frac{1}{l'} - \frac{1}{l} = \frac{1}{f'}$$
$$l' = l'_1 - 20mm, \frac{1}{f'} = \frac{1}{f'_1} + \frac{1}{f'_2}$$

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.

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

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

$$\Delta = d - f'_1 + f_2$$

$$\frac{1}{f_2} = \frac{n-1}{nr_2}, f_2 = -900mm, \Delta = -250mm$$

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

$$l_2 = f'_1 - d = -650mm$$

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

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.

$$l'_1 = \frac{nr}{n-1} = 480mm$$

$$\frac{2}{r} = \frac{1}{80mm}$$

$$r = 160mm, n = 1.5$$

13. 条件一：间隔不变，物距任意，放大率不变

$$x_1 x'_1 = -f'^2_1$$

$$-x_2 = d - x'_1 - f'_1 - f'_2$$

$$x_2 x'_2 = -f'^2_2$$

$$\beta = \beta_1 \beta_2 = \frac{f'_1}{x_1} \frac{f'_2}{x_2} = \frac{f'_1 f'_2}{(f'_1 + f'_2 - d)x_1 - f'^2_1} = constant$$

$$\frac{1}{\beta} = \frac{(f'_1 + f'_2 - d)x_1 - f'^2_1}{f'_1 f'_2}$$

$$\frac{d(\frac{1}{\beta})}{dx_1} = 0 = \frac{f'_1 + f'_2 - d}{f'_1 f'_2}$$

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.

$$l_1 = f_1, l'_1 = \infty$$

$$l_2 = \infty, l'_2 = f'_2$$

$$\Delta = d - f'_1 - f'_2$$

$$\beta = \beta_1 \beta_2 = \frac{f_1 l'_1}{f'_1 l_1} \frac{f_2 l'_2}{f'_2 l_2} = \frac{l'_1 l'_2}{l_1 l_2} = \frac{f'_2}{-f'_1}$$

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

$$x'_F = \frac{f'^2_2}{d - f'_1 - f'_2}$$

15. $r_1 = 120mm, r_2 = -320mm, d = 30mm, n = 1.6$

$$f_1 = \frac{r_1}{1-n} = -200mm, f'_1 = \frac{nr_1}{n-1} = 320mm, f_2 = \frac{nr_2}{n-1} = -\frac{2560}{3}mm, f'_2 = \frac{r_2}{1-n} = \frac{1600}{3}mm$$

$$\Delta = d - f'_1 + f_2 = -\frac{3430}{3}mm$$

$$f' = -\frac{f'_1 f'_2}{\Delta} = \frac{51200}{343}mm$$

$$x'_F = -\frac{f_2 f'_2}{\Delta} = -398.056mm, x_F = \frac{f_1 f'_1}{\Delta} = \frac{19200}{343}mm$$

$$l_H = f_1 + x_F - f = 5.248mm, l'_H = f'_2 + x'_F - f' = -13.993mm$$

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

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

17. 注：这里实际上 f_1 为 f_1'

$$h_1 = f_1' \tan(U_1') = 50mm$$

$$h_2 = h_1 - d_1 \tan(U_1') = 45mm, \tan(U_1') = \tan(U_2) = \frac{h_1}{f_1'} = 0.5$$

$$\tan(U_2') = \tan(U_3) = \tan(U_2) + \frac{h_2}{f_2'} = 1.4, h_3 = h_2 - d_2 \tan(U_2') = 31mm$$

$$\tan(U_3') = \tan(U_3) + \frac{h_3}{f_3'} = 0.78, f = \frac{h_1}{\tan(U_3')} = 64.102mm$$