Exercise 6-1: Aplanatic Lens

Consider a meniscus shaped lens with thickness \( d = 3 \) mm, refractive index \( n = 1.5 \) and front radius of curvature \( r_1 = 100 \) mm. Calculate the back radius of the lens to get an aplanatic component. Calculate the focal length and the Petzval radius of the lens. Calculate the image sided intersection length, the magnification and the bending parameter of the lens. If the incoming numerical aperture is \( NA = 0.2 \), what is the image sided numerical aperture?

Exercise 6-2: Nonlinearity at a Single Plano-Convex Lens

Assume a collecting plane-convex lens with spherical rear surface \( R \). The incidence angle at the rear surface is \( i \). If the lens is turned around, the incidence angles at the front and the rear surface are approximately \( i/2 \) respectively. Compare the degree of nonlinearity due to exact law of refraction for these two configurations of the lens in the third order approximation. How can the well-known rule be understood to orient the lens in the proper way for focusing with the lens?

Exercise 6-3: Mangin Mirror

A Mangin mirror is a negative meniscus lens with index \( n \), which is reflective at its rear surface. The setup looks as follows.
a) Calculate the focal length of the system
b) With the help of the surface contribution formula

\[ A_s = -\frac{n'(n'-n)}{8n^2} \left( \frac{1}{R} - \frac{1}{s'} \right)^2 \left( \frac{n'}{R} - \frac{n'+n}{s'} \right) \]

show that the spherical aberration of the system for incoming parallel light is given by

\[ A_s = -\frac{n-1}{4n^2} \left[ \frac{1}{R_1^3} + \frac{n+3}{2R_1^2f'} + \frac{4n+5}{4R_1f'} + \frac{4n^2-3}{8(n-1)f'^3} \right] \]

If in particular the front surface should be concentric to the outgoing focusing beam, what is the condition for the refractive index to get a spherical corrected system?

c) Calculate the Petzval curvature of the system. What is the value of the front radius for given \( n \) and \( f' \) to get a flattened imaging system?

**Exercise 6-4: Dyson System**

The so called Dyson system is a very clever setup, which can be used for some imaging applications with a quite good correction. A typical layout is shown in the following figure. All the curved surfaces are of spherical shape, the surface in the object and image plane respectively is plane.

a) What are the remaining aberrations of the system in the general case of arbitrary parameters? Sketch the system, if the mirror is unfolded and considered it as a positive thin lens.
b) If the parameters are chosen as \( t_L = -r_L \) and \( t_L + t_a = -r_M \), what is the consequence for the aberrations?

c) What is in addition the necessary condition for the parameters to correct the Petzval field curvature in 3\(^{rd}\) order? What should therefore be the radius \( r_L \) of the lens, if the glass index is \( n = 1.5 \) and the mirror has the radius \( r_M = 100 \text{ mm} \)?

d) What is now the only remaining primary aberration of the system?