CHAPTER 1-2-3: Introduction

Ex1. Single Lens

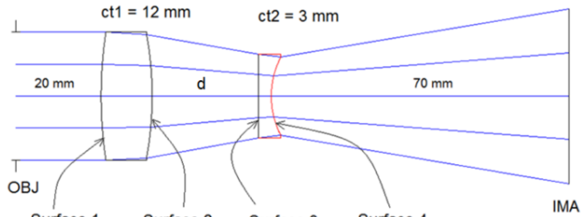
Consider a bi-concave lens whose center thickness is 5 mm, aperture is 35 mm, and glass is N-BK7. The object is at infinity, wavelength λ = 0.6 μm, and radii $|R_1|$ = 100 mm and |R2| = 120 mm.

(a) What is the effective focal length of the lens?
(b) What is the back focal length of the lens?
(c) What is the front focal length of the lens?
(d) What is the mass of the lens?
(e) What is the edge thickness of the lens?

Ex2. Two Lenses

Let λ= 650 nm and ENP = 25.4 mm.

(a) Implement the following system in Zemax LDE.
(b) What is the effective focal length of the system?
(c) What is the back focal length of the system?
(d) What is the front focal length of the system?
(e) What is the spot radius on the image plane?
(f) For which value of distance *d* the system is afocal?



Ex3. Cooke Triplet

The Cooke triplet is a photographic lens designed and patented (patent number GB 22,607) in 1893 by Dennis Taylor.
See also:
https://en.wikipedia.org/wiki/Cooke_triplet
Implement the lens data given right in Zemax.

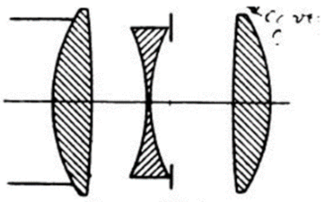


Fig. 94, s. Taf. I.
H. D. TAYLOR: Portraitobjektiv.
Quelle: H. D. TAYLOR. 1.

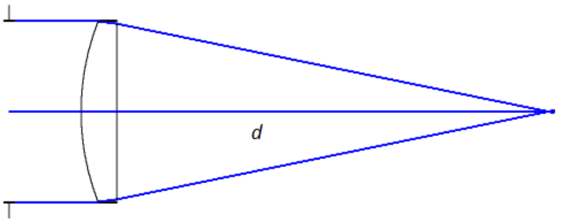
Reducirt auf f_D = 100 mm.
Durchgerechnet für 1:4 und $\omega = 13°$.
Radien r_ν, Dicken d_ν und Abstände b_ν in Millimetern auf der Axe gemessen.

r_1 = 26.4
d_1 = 5.9
r_2 = 150.7
b_1 = 10.9
r_3 = 29.8
d_2 = 0.2
r_4 = 24.2
b_2[1]) = 8.1
b_2[2]) = 9.4
r_5 = 150.7
d_3 = 5.9
r_6 = 26.4

Glasarten n_D.
$L_1 = L_3$ = 1.5108
L_2 = 1.6042

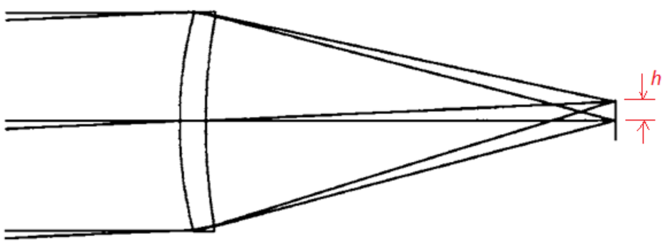
Ex4. A plano-convex lens

ct = 5 mm
ENPD = 25 mm
f/# = 4
Glass = N-BK7
Wavelength = 0.55 μm
R_2 = inf
R_1 = ? (radius of curvature of 1st surface)
d = ?   (distance between 2nd surface and image plane where we have smallest spot size)



Ex5. Thermal Infrared Lens

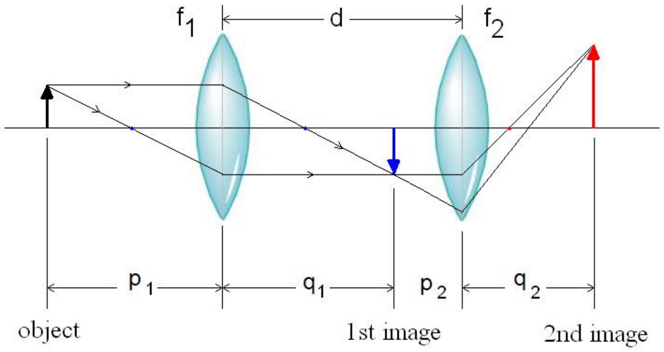
Glass = Germanium
ENPD = 25 mm
f/# = 2
R_1 = 49.030 cx (cx means convex)
R_2 = 69.460 cc (cc means concave)
ct = 3 mm
Wavelength = 10 μm
Full FOV = 5°



(a) Find the back focal length of the lens. (Hint use quick focus)
(b) Find the image height h.

CHAPTER 4: First Order Optics

Ex1. Two Thin Lenses
Consider the system given right.
Show that back, front and effective focal length of the system are respectively given by:



$$BFL = \frac{f_2(d - f_1)}{d - (f_1 + f_2)}$$
$$FFL = \frac{f_1(d - f_2)}{d - (f_1 + f_2)}$$
$$EFL = \left[\frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}\right]^{-1}$$

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Ex2. For the system given in Ex1, find EFL, BFL and FFL of the system if f_1 = -30 mm, f_2 = +20 mm and d = 10 mm. Implement your solution in Zemax and compare your results.

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Ex3. For the system given in Ex1, find the final image position and its magnification for an object placed at p_1 = 30 cm if f_1 = +100 mm and f_2 = +200 mm and d = 200 mm.

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Ex4. For the system given in Ex1, what focal lengths are necessary in this two-element lens system if one requires a 200 mm (effective) focal length, a 100 mm back focus, and a 50 mm air space?

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Ex5. Pupils
A lens of +50 mm focal length is mounted in another lens lens but of -70 mm focal length. The distance between lenses is 60 mm. When a stop 5 mm in diameter is placed halfway between the two lenses,
(a) what is the location and diameter of the entrance pupil? and
(b) what is the location and diameter of the exit pupil?
Use Zemax to verify the results.

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Ex6. Cooke Triplet
Three thin lenses are arranged in the following order: a positive lens (f = 60 mm, d = 8 mm) separated 13 mm from a negative lens (f = -40 mm, d = 6.4 mm) and followed by another positive lens (f= 50 mm, d = 7.2 mm) with a separation of 13 mm from the negative lens. Assume that second lens is the aperture stop.

(a) What is the effective focal length of the system?
(b) Where are pupils for an object at infinity?
(c) If an object is 300 mm from the first lens, where are the image and pupils for the system?

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Ex7. Find the image distance for an object positioned 200 mm from the vertex of a double concave lens having radii 100 mm and 200 mm, a thickness 5 mm, and index of n = n_L = 1.5.

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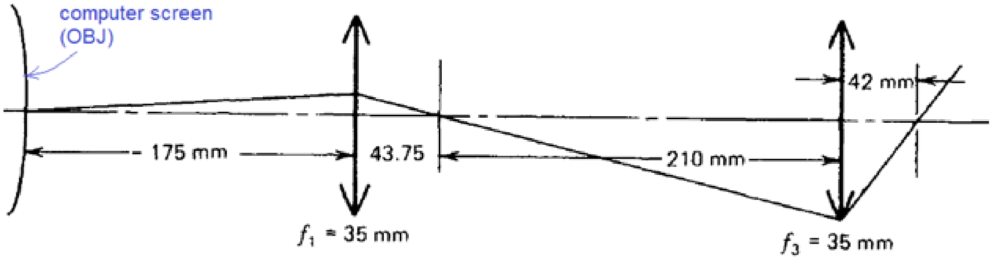
Ex8. Using Fermat's principle, show that parallel rays falling on a concave mirror can only be focuced on a single point if it is a parabolid.

CHAPTER 5: Ray Tracing

Ex1. An application of y-u trace
Consider a simple optical system in Figure below. Starting with $(y_0, u_0) = (0, 0.1)$, find the final height and slope angle of this ray.



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Ex2. Paraxial Lenses
The focal lengths of four thin lenses are f_1 = 100 mm, f_2 = -50 mm, f_3 = 80 mm, and f_4 = -280 mm. Separations between the lenses are t_1 = 20 mm, t_2 = 40 mm, and t_3 = 30 mm. Using Zemax, find the image location if the object is 400 mm from the first lens. Check your results using y-u trace.

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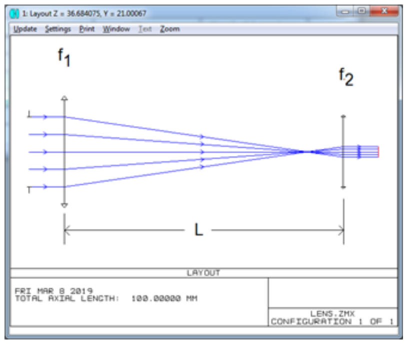
Ex3. Keplerian Telescope
Figure shows a Keplerian (or Astronomical) Telescope consisting of two positive thin lenses.Use y-u trace.
(a) Show that the entrance and exit rays are parallel to the optical axis when $L = f_1 + f_2$.
(b) What is the magnification of the system when $L = f_1 + f_2$?
(c) What is the back focal length of the system when $L = (f_1 + f_2)/2$?



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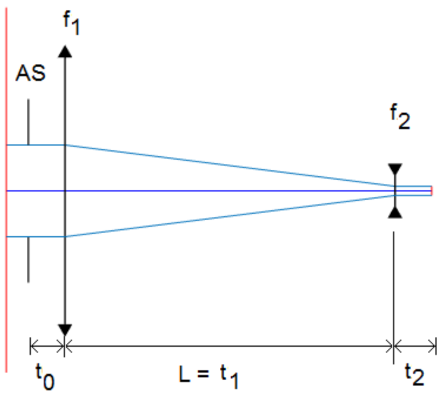
Ex4. Galilean Telescope
Figure shows a simple Galilean Telescope consisting of two thin lenses.
Let f_1 = 100 mm, $f_2 < 0$, $t_0 = t_2$ = 10 mm and diameter of AS is 20 mm.
We want to design an afocal system. Use y-u trace.
(a) Show that the distance between lenses must be $L = f_1 + f_2$.
(b) Show that magnification of the system is given by $m = -f_1/f_2 = D_{EnP} / D_{ExP}$ where D_{EnP} and D_{ExP} are diameters of the enterance and exit pupils respectively.
(c) For which value of f_2 and L, the system's exit pupil diameter is 4 mm?
(d) For the values of L and f_2 in part (c), determnine the location and diameter of EnP and ExP?



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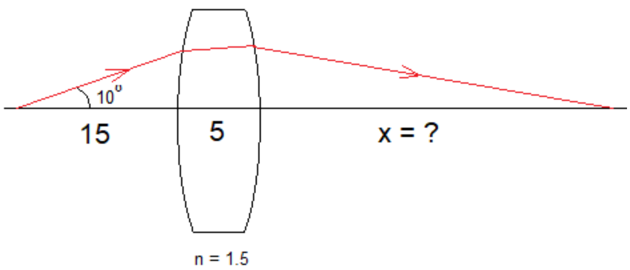
Ex5. Perform paraxial and real ray tracing for a given ray in figure. Determine value of x for each case and compare your results. Assume that radius of curvature of first lens is R_1 = 100 mm and of second surface is R_2 = -100 mm.



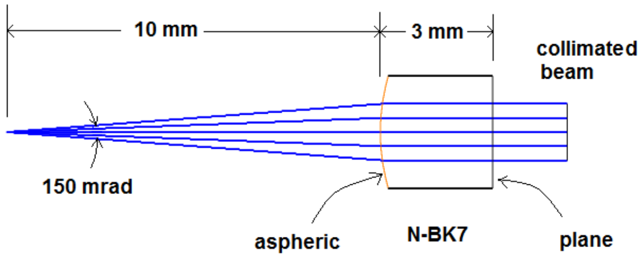
CHAPTER 6: Optimization

Ex1. Design and optimize an f/5 singlet lens made of N-SF10 glass. The final design solution should meet the specifications and constraints given in the table.

Specification	Constraint
Focal Length	70 mm
Semi-Field of View (SFOV)	5 degrees
Wavelength	532 nm
Center Thickness of singlet	Between 2 mm and 12 mm
Edge Thickness of singlet	Larger than 2 mm
Optimization criteria	RMS Spot Size averaged over FOV
Object location	At infinity

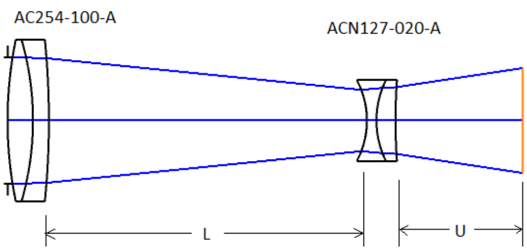
Ex2. Figure below shows a plano-hyperbolic collimator made from N-BK7 glass. It is used to collimate a laser diode whose beam divergence is 150 mrad and wavelength is 633 nm.

(a) Determine the proper diameter of the collimating lens.
(b) Find the radius of curvature and the conic constant of the aspherical surface to collimate the light properly.
(Hint: the system is afocal)



Ex3. Figure shows an optical system with two lenses selected from Vendor "Thorlabs" Lens Catalog (AC254-100-A and ACN127-020-A). System aperture is ENPD = 20 mm,
FOV = 1° (±0.5°), wavelength is λ = 600 nm and the object is at infinity.

(a) For U = 10 mm, determine the value of L such that the system is afocal.
(b) For U = 10 mm, determine the value of L such that the system has minimum spot size at image plane.

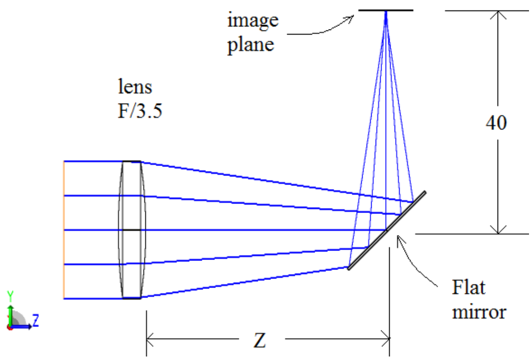


Ex4.
Design the following optical system containing a lens and a flat mirror
System:
* ENPD = 25 mm, λ= 405 nm, Object is at infinity

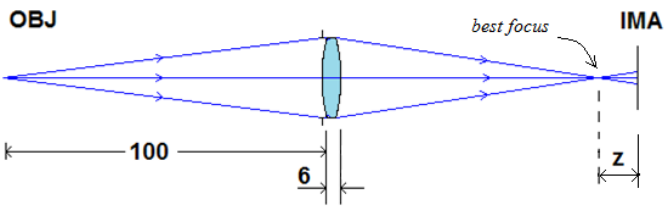
Lens
* 1st surface radius R_1= 100 mm, ct = 5 mm
* Glass = K5, F/# = 3.5

Plane Mirror
* Diameter = 10 mm

(a) Determine the radius of curvature of 2nd surface of the lens.
(b) Find the optimum distance (Z) between 2ndsurface of the lens and mirror such that the spot size on the image plane is minimum. Use default merit function.

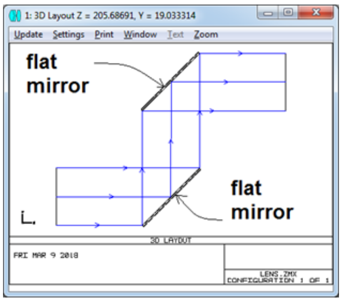


Ex5. Figure shows an equi-convex lens ($|R_1|$ = $|R_2|$ = 50 mm, t = 6 mm) made from N-BK7. Entrance pupil of the system is 25 mm. Initially the image plane is placed at the paraxial focus. The distance between STOP and first surface of the lens is zero. Using Zemax, determine the position z (with respect to initial image plane location) corresponding to minimum spot radius for Fraunhoffer C line.

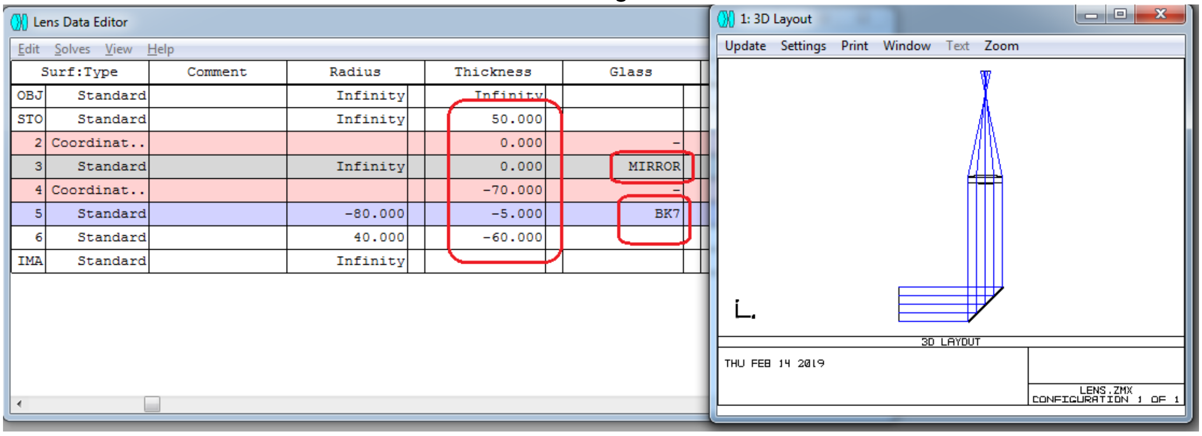


CHAPTER 7: Some Optical Instruments

Ex1. Basic Periscope with two mirrors
Fulfill the fold mirror simulation as shown in Figure in Zemax.



Ex2. Fulfill the fold mirror and lens simulation as shown in Figure in Zemax.



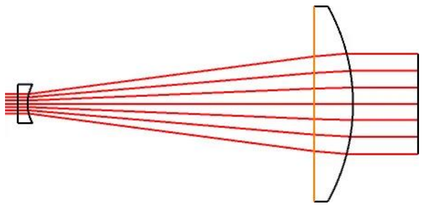
Surf:Type		Comment	Radius	Thickness	Glass
OBJ	Standard		Infinity	Infinity	
STO	Standard		Infinity	50.000	
2	Coordinat..			0.000	-
3	Standard		Infinity	0.000	MIRROR
4	Coordinat..			-70.000	-
5	Standard		-80.000	-5.000	BK7
6	Standard		40.000	-60.000	
IMA	Standard		Infinity		

Ex3. For two spherical mirrors, derive Cassegrain Telescope Design Equations via paraxial ray tracing equations.

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$ and $d + b = \left(1 - \frac{d}{f_1}\right) f$

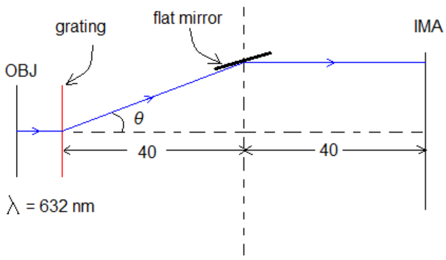
Ex4. Design a Cassegrain Telescope whose focal length is 1.2 m, aperture 0.2 m and distance between mirrors is 0.4 m. Determine radius of curvatures and conic constants for each mirror.

Ex5. 5X Beam Expander, Galilean system.
Select two lenses from Edmund Optics Stock.
#45-008: A 6mm diameter plano-concave lens with a -12mm focal length
#45-127: A 25mm diameter plano-convex lens with a 60mm focal length.
Optimize for 3 mm input beam and the output beam will be 15 mm.
Assumed the laser Helium Neon (HeNe) is used in the design.



Ex6. Using stock lenses
(a) Design an Astronomical telescpoe whose total length is 60 cm and magnifying power M = 10x.
(b) Design a Galilean telescpoe whose total length is 60 cm and magnifying power M = 10x.

Ex7. A mirror and a Grating
A monochromatic laser beam (λ= 632.8 nm) is falling on a grating with 600 lines/mm. Diffracted first order beam (m = 1) falls on a plane mirror and it is reflected as shown.
(a) Find diffraction angle, θ.
(b) Using Zemax, design the optical system such that the reflected ray from mirror is parallel to the optical axis.



Ex8. Eye Models in Zemax

- https://support.zemax.com/hc/en-us/articles/1500005575002-How-to-model-the-human-eye-in-OpticStudio
- https://support.zemax.com/hc/en-us/articles/7772225130259-Realistic-modeling-of-relief-type-diffractive-intraocular-lenses-using-User-Defined-Surface-DLLs