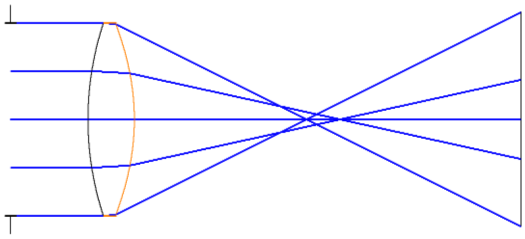
CHAPTER 8-11: Aberrations and Diffraction

Ex1. Singlets with best shape

Consider a singlet.

ENPD = 20 mm,
EFFL = 80 mm (f/4)
ct = 3 mm
λ = d-line
FOV = 0



For an object at infinity, find the radii of curvatures of singlet resulting in minimum spherical aberration for index of refraction n = 1.5, 2.0, 3.0, 4.0. For each of them, investigate aberration plots, Seidel diagrams, RMS spot radius, ray fan, etc.

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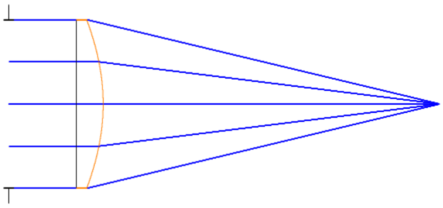
Ex2. Aspherical singlet lens

Design a plano-convex aspheric lens whose focal length is 50 mm, index n = 1.6 and f/# = 2.

Optimize the lens such that it has minimum S.A.

(a) Use only conic constant (Radius and Conic are variable)
(b) Use only Even Asphere (Radius and A2 and A4 are variable)
(c) Use both (Radius, Conic and A2 and A4 are variable)



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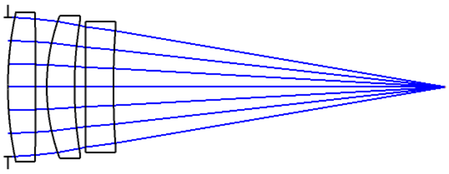
Ex3. Triplet Design

Design a triplet lens system whose focal length is 75 mm (for d-line) and aperture 25 mm such that it has minimum spherical aberration. For all lenses, material is N-BK7, ct = 5 mm and distance (thickness) between any two of them is 2 mm.



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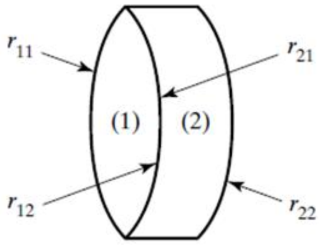
Ex4. Achromatic Doublet Design

Consider two glasses which are cemented together to be used in designing an achromatic lens,

EFFL = 125 mm (d-line)
ENPD = 30 mm
GLAS = SCHOTT
WAVE = F, d, C visible
SFOV = 1°.
ct1 and ct2 = 3-8 mm



(a) Determine the radius of curvatures and optical materials via optimization tool of Zemax.
(b) Repat the same procedure for spaced doublet design (Let the distance between lenses be in the range [0, 2] mm)

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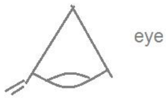
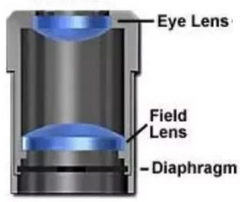
Ex5. Ramsden Eyepiece

Design a Ramsden Eyepiece (a spaced doublet made from same glasses) whose specifications are as follows:

EFFL = 25 mm (d-line)
ENPD = 6 mm
GLAS = SCHOTT
WAVE = F, d, C
SFOV = 10°
ct1 and ct2 = 3-8 mm
ER = 10 mm
60 < TOTR < 75 mm

You may use the following Zemax operands in the optimization.
EFFL, AXCL, LACL, TOTR, OPLT, OPGT





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Ex6. Keplerian Telescope

Combine two systems in Ex4 and Ex5 to make a 5X Keplerian Telescope.

Ex7. Eye piece with eye
Using Zemax eye model and eyepiece in Ex5.

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Ex8. Consider an optical system used in the near infrared (NIR) range.
Use two lenses made from same material.

- Material	: F2
- Wavelength	: 1064 nm
- We need to resolve	: 0.1 NATO mil* in object space
- ct1 and ct2	: 3-8 mm
- Full FOV	: 3.6^{o}.
- Detector	: CCD with 10 μm pixel size (pitch)
- TOTR	: [100 mm, 200 mm]
- Max Distortion	: 1 %

(a) Determine focal length, f/#, clear aperture, depth of focus of the system and Nyquist frequency of sensor.
(b) Using Zemax, determine radii of curvatures of lenses such that the system has the best performance.
(c) For the optimized system, determine the values of max OPD and MTF at Nyquist frequency?

* *1 NATO mil (also known as artillery mil) is an angle defined by 1 / 6400 of a circle.*
1 circle = 2π rad = 360 deg = 6400 NATO mil = 400 grad
Hence, 1 NATO mil ≈ 1 mrad ≈ 0.057 deg.
In Turkish Army, we use the term Milyem instead of NATO mil.

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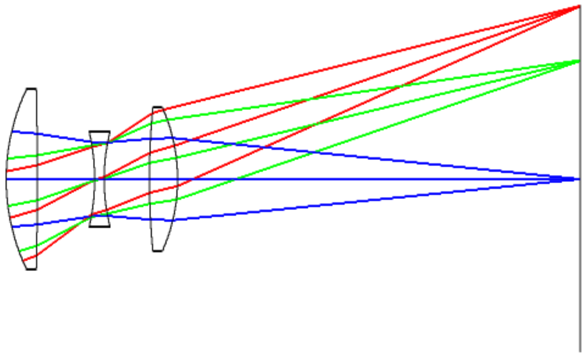
Ex9. Achromatic Doublet Objective Design
Design the following achromatic doublet lens using BK7-SF2 glass pair:

Entrance pupil diameter	50 mm
Focal length	250 mm (d-line)
f/#	5
SFOV	2 deg
Spectral range	Visual (F, d, C)
ct(BK7)	5-8 mm (variable)
ct(SF2)	4-7 mm (variable)
Object	at infinity

(a) Using thin lens equations given in the lecture determine the radius of curvatures of the lenses.
(b) Set all radii of curvatures, center thickness, and distance between last surface & image plane as variable. (totally 6 variables). Optimize the system to obtain minimum RMS spot size averaged over FOV. What are the optimum values of these 6 parameters?
(c) Determine the minimum pixel size of the sensor required.
NOTE: You can use EFFL, AXCL and LACL operands in the merit function.

Ex10. Investigate aberration and MTF plots of the objective named “Cooke 40 degree field.zmx” which can be found under c:\<zemax>\Samples\Sequential\Objectives.



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Ex5. The table shows index of refraction of common optical plastics (polymers). Use any of these two materials to design an achromatic lens whose entrance pupil diameter is 40 mm and focal length is +120 mm for Fraunhoffer F,d,C lines and FOV ±2º.

Wavelength (nm)	PMMA	Poly-styrene	Poly-carb.
365.0	1.5136	1.6431	1.6432
404.7	1.5066	1.6253	1.6224
435.8	1.5026	1.6154	1.6115
480.0	1.4983	1.6052	1.6007
486.1	1.4978	1.6041	1.5994
546.1	1.4938	1.5950	1.5901
587.6	1.4918	1.5905	1.5855
589.3	1.4917	1.5903	1.5853
643.9	1.4896	1.5858	1.5807
656.3	1.4892	1.5849	1.5799
706.5	1.4878	1.5820	1.5768
852.1	1.4850	1.5762	1.5710
1014.0	1.4831	1.5726	1.5672
Abbe number	57.4	30.9	29.9
Density (g/cc)	1.19	1.20	1.06