OPTI-502 **Optical Design and Instrumentation I** John E. Greivenkamp
Homework Set 11 Fall, 2009

Assigned: 11/10/09 Lecture 23
Due: 11/17/09 Lecture 25

11-1) A Petzval objective is comprised of two thin lenses separated by 75 mm. The two thin lenses have the same focal length, and the effective focal length of the system is 100 mm. The system is telecentric in image space, and the object is located 250 mm to the left of the first lens. The stop diameter is 20 mm, and the object height is 20 mm. Determine the focal lengths of the thin lenses, the stop position, and the required diameters of the two lenses for the system to be unvignetted.

11-2) A 5x Keplerian telescope has a 200 mm focal length objective. The objective lens serves as the system stop and has a diameter of 40 mm.

a) What is the required eye lens diameter for the telescope to have an unvignetted field of view of +/- 2 degrees?
b) Convert the telescope into a doubly telecentric system. Where is the stop location?
c) Two objects are located 400 mm and 100 mm to the left of the objective lens. Where are the respective image planes (relative to the second lens)?

11-3) Design a 200X optical microscope with a 20X objective and a 10X eyepiece. The optical tube length is 200 mm. The optical tube length is the distance from the rear focal point of the objective to the front focal point of the eyepiece or the intermediate image plane. Assume a simple eyepiece.

a) Provide the focal lengths and spacings of the two lenses. Determine the working distance.

b) If the diameter of the objective lens is 6.0 mm and the diameter of the eyelens is 5.0 mm, what is the unvignetted field of view (in mm) of the microscope? The objective lens is the system stop.

11-4) The combination of an objective lens and a relay lens can be thought of as a single compound objective. If the objective focal length is 100 mm, the relay focal length is 25 mm, and the separation of these two elements is 150 mm, what is the focal length of the combination of the two lenses? Explain your result in terms of the rear focal point and principal planes of this two-element system and why this relative order occurs.

11-5) A biconvex lens is formed by polishing identical convex surfaces of radius R = 50 mm on both ends of a glass rod of index n = 1.5.

a) For an object at infinity, sketch plots of the system focal length and paraxial image location as a function of the length of the rod (measure the image location relative to the rear vertex, and consider positive thicknesses from 0 to 500 mm only).

Hint: To simplify the calculations, first solve for the focal length and image location in terms of the reduced thickness of the rod.

b) As the rod length changes, several classes of two-element optical instruments are generated. Identify these classes as well as specific systems and qualitatively explain their image-forming operation in terms of an equivalent pair of thin lenses. Ignore all reflections.

11-6) Design a pair of 8X40 binoculars:

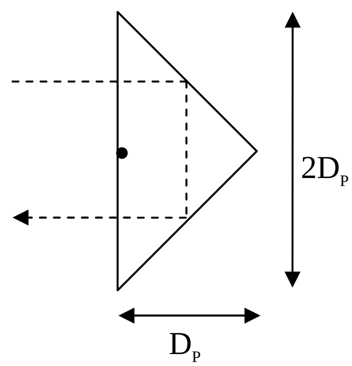
Actually, you only need to design one monocular of the binocular.

Specifications:

Objective Focal Length = 200 mm
Eye Relief = 15 mm
The system stop is at the objective.
A field lens is placed at the intermediate image plane.

A Porro Prism System is used for image erection. The index of refraction of the prisms is 1.517, and both Porro prisms that make up the Porro system must be the same size. For mechanical mounting reasons, none of the optics of the binoculars may be inside the "mechanical volume" of the Porro system. The mechanical volume of the Porro system is the smallest rectangular volume that will contain the prism system. The length of this volume is defined by the dihedral lines of the two component Porro prisms.

The defining dimension of the Porro system is the entrance face size D_P. The entrance face of one of the Porro prisms is D_P x D_P. The cross section of each Porro prism is shown.



IMPORTANT **--** A summary page of the system is attached where all of the pertinent details of your design must be shown. This summary page is to be used as the cover page of your solution.

Note: This is a first-order design problem. All lenses can be assumed to be thin lenses in air with no aberrations and no thickness. Similarly, mirrors have radii of curvature but no sag. To aid in grading, this problem may be more completely specified than you would normally encounter. In fact, the approach specified may or may not be the "best" form of the solution.

All of the given specifications must be met exactly.

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Section A

Determine the required Porro prism system size that produces an unvignetted full field of view of +/- 2.0 degrees. The Porro prism system must be as small as possible.

Determine: Prism Size (Minimum) D_P

Section B

Using the Porro prism from Section A, complete the design to provide the largest possible half-vignetted Field of View.

Determine the following:

Half-Vignetted FOV	FOV_{HALF}
Eye Lens Focal Length	f_E
Field Lens Focal Length	f_F
Objective Lens Diameter	D_O
Eye Lens Diameter	D_E
Field Lens Diameter	D_F
Objective Lens to Prism Entrance Face Distance	t
Overall Mechanical System Length*	L

*The mechanical system length is the distance between the objective lens and the eye lens (measured parallel to the optical axis) of the binocular system.

Section C

Redesign the 8X40 binoculars to have the largest possible half-vignetted field of view. Use the same initial specifications for the objective and the stop and field lens locations.

Determine the following:

Prism Size	D_P
Half-Vignetted FOV	FOV_{HALF}
Eye Lens Focal Length	f_E
Field Lens Focal Length	f_F
Objective Lens Diameter	D_O
Eye Lens Diameter	D_E
Field Lens Diameter	D_F
Objective Lens to Prism Entrance Face Distance	t
Overall Mechanical System Length	L

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NAME ______________________________ Cover Sheet for Solution

Sections A and B

Prism Size	D_P = __________mm
Half-Vignetted Field of View	FOV_{HALF} = +/-________ degrees
Eye Lens Focal Length	f_E = __________mm
Field Lens Focal Length	f_F = __________mm
Objective Lens Diameter	D_O = __________mm
Eye Lens Diameter	D_E = __________mm
Field Lens Diameter	D_F = __________mm
Objective Lens to Prism Entrance Face	t = __________mm
Overall Mechanical System Length	L = __________mm

Section C

Prism Size	D_P = __________mm
Half-Vignetted Field of View	FOV_{HALF} = +/-________ degrees
Eye Lens Focal Length	f_E = __________mm
Field Lens Focal Length	f_F = __________mm
Objective Lens Diameter	D_O = __________mm
Eye Lens Diameter	D_E = __________mm
Field Lens Diameter	D_F = __________mm
Objective Lens to Prism Entrance Face	t = __________mm
Overall Mechanical System Length	L = __________mm

Surface	0	1	2	3	4	5	6	7	8	9
f										
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t										
y										
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