OPTI-502 **Optical Design and Instrumentation I** John E. Greivenkamp

Homework Set 10 Fall, 2009

Assigned: 11/3/09 Lecture 21
Due: 11/10/09 Lecture 23

Deferred from HW#9

9-6) Design a Galilean telescope with a magnifying power of 5 and a length of 100 mm. Specify the two focal lengths.

9-8) Two stars are separated by 2.0 arc seconds. Assuming the eye has a resolution of 1 arc minute, what magnifying power is required for a telescope in order to visually resolve the stars? If diffraction is included, what is the minimum required entrance pupil diameter?

9-10) A Keplerian telescope has the following specifications:

Magnifying Power = 12 X
Length = 260 mm (objective to eye lens)
Unvignetted Field of View = +/- 2 degrees
Eye Relief = 15 mm
Entrance Pupil Diameter = 40 mm
The stop is located at the objective lens of the telescope
The object is at infinity
All elements are thin lenses

Design the telescope. How many elements are required? Provide element focal lengths, diameters and spacings. Be sure to verify that all of the above specifications are met exactly.

10-1) Design three different eyepieces for an optical system. All three eyepieces have a Magnifying Power of 10, and are to be used with a relaxed eye (the image presented to the eye is at infinity). The system objective presents an intermediate image to the eyepiece, and the intermediate pupil of the system is 200 mm to the left of this intermediate image plane. This intermediate pupil is the image of the stop through any optical elements between the stop and the eyepiece.

a) A simple eyepiece consisting of just an eye lens. Determine the focal length and the eye relief.
b) A compound eyepiece with a field lens located at the intermediate image plane. The field lens has a focal length of 40 mm. Determine the eye relief.
c) A Ramsden-style eyepiece with the same eye relief as found with compound eyepiece of part (b). The field lens is located 12 mm to the right of the intermediate image plane. Determine the focal lengths of the two lenses and their separation. Hint: Three conditions must be met by the design -- the eyepiece must have the proper magnifying power, the final image presented to the eye must be at infinity, and the required eye relief must be obtained.

10-2) Eyeglasses are used when the focus of the eye does not fall on the retina. With myopia (nearsightedness), rays from a distant object focus in front of the retina. With hyperopia (farsightedness), these rays focus behind the retina. For the purposes of this problem, the eye can be modeled as a spherical refracting surface of index n.

a) Eyeglasses are usually placed near the front focal point of the eye (assume they are at F). If ϕg is the power of the eyeglasses and ϕe is the power of the eye, what is the system power?
b) Based on this answer, how do eyeglasses work?
c) What happens if the eyeglasses are not at the front focal point of the eye?
d) What is the sign of the power required to correct myopia and hyperopia?
e) As a comparison, how do contact lenses work?

10-3) The goal of this problem is to design a door peephole to view your visitors (you see them, but they don't see you). The eye should be included as part of the design, and for this problem we will model the eye as a single refracting surface of radius 5.65 mm. The index of the eye is that of water (1.333), and the pupil or iris diameter is 4 mm and is located at the cornea. The retina is located at the rear focal point of the cornea. The macula is the central portion of the retina and is specialized for resolution. The fovea is the highest resolution part of the macula and has a diameter of about 1.5 mm. The resolution of the retina drops off outside the macula. The macula has a diameter of about 3 mm, and we will somewhat arbitrarily use an area of about 1.5 times the macula diameter to define the visual field of view for this application.

The peephole is a non-inverting afocal system used to increase the field of view of the eye through the door. The iris of the eye is the system stop.

a) Design a thin-lens peephole that covers a total field of 90° and has a total length of 25 mm (it has to fit within the thickness of the door).

b) What are the required element diameters for a totally vignetted field of this size? The separation between the cornea and the rear element of the optical system should also be 25 mm (nose room).

c) Given that the illuminance produced by a full moon on the earth's surface is 0.27 lm/m2, what is the illuminance produced on the retina using this system? Remember that the image at the retina is in water.

10-4) A 10X Keplerian telescope is constructed out of a 200 mm focal length objective lens and a 20 mm focal length eye lens. The system stop is at the objective.

a) What are the length (from objective lens to eye lens) and eye relief of this telescope?

b) Add a relay lens to the telescope to correct the image orientation and to increase the magnifying power of the telescope to 20X. The focal length of this lens is 30 mm. What are the element separations, the system length and the eye relief?

c) Now add a field lens at the first intermediate image plane of the telescope to image the objective lens (stop) of the system into the relay lens aperture. The overall system length does not change. Determine the focal length of this field lens and the eye relief.

d) If the system has a field of view of +/- 1 degree, what are the required diameters of the field lens and the relay lens? The objective diameter is 20 mm.

10-5) The purchasing department made a large mistake and ordered several hundred thousand 50 mm focal length lenses for a now-cancelled program. Faced with the dilemma of what to do with all these non-returnable lenses (and sensing an opportunity to single-handedly save the company), your boss walks into your office and proclaims "Riflescopes – the future is riflescopes!"

Section A

Your boss now orders you to design a 3X25 riflescope using only these 50 mm focal length thin lenses. Your boss also insists that you only use three of these lenses per riflescope. A riflescope is a relayed Keplerian telescope (afocal with an erect image). The stop is at the objective lens, and the object can be considered to be at infinity.

For this three-element system, determine the element spacings, locations of any intermediate image planes (for crosshairs), the overall system length, the eye relief and the XP diameter.

Section B

The object space FOV of the riflescope is 3 degrees (HFOV is 1.5 degrees). Determine the required element diameters for this three-element system to be unvignetted over this FOV. Provide a system layout showing the marginal ray. (At this point in the design process, you do not know the available element diameters.)

Section C

Your boss reviews your three-lens design and says "That's nice, but all the lenses we have are only 25 mm in diameter." What are the implications of this limitation to your design? Can you provide a 3X25 design using just three of these lenses?

Section D

Confident in your abilities, your boss now demands that you design a 4X25 riflescope with an overall length of exactly 300 mm (objective to eye lens). As a single concession, you are now permitted to use four of the 50 mm focal length thin lenses. The stop is at the objective, and the full unvignetted FOV remains at 3 degrees. The design approach is to replace the relay lens with an air-spaced pair of lenses.

As before, provide the element spacings, locations of any intermediate image planes (for crosshairs), the overall system length, the eye relief, the XP diameter, and the required element diameters. Provide a system layout showing the marginal ray.

Does this four-element system assembled out of existing equal lenses look like a reasonable design for a riflescope?

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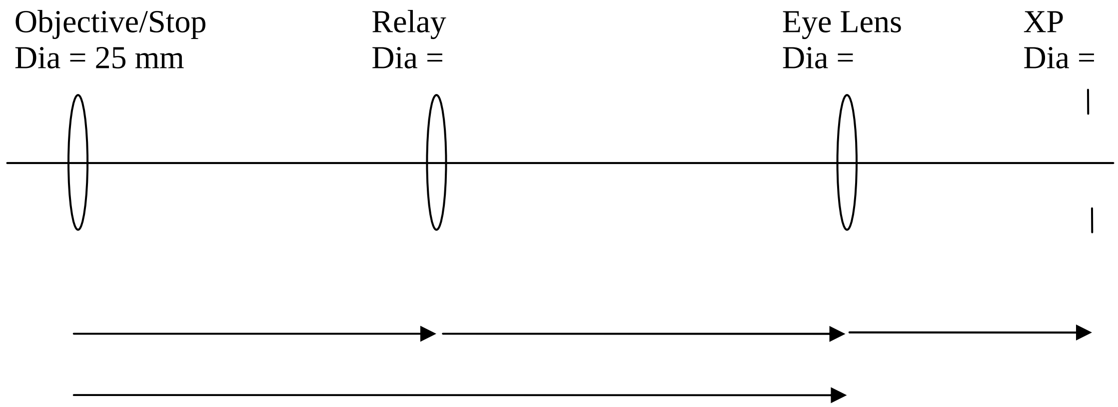
Note: This is a first-order design problem. All lenses can be assumed to be thin lenses with no aberrations and no thickness. To aid in grading, this problem may be more completely specified than you would normally encounter. In fact, the approach specified may or may not be the "best" form of the solution.

All of the given specifications must be met exactly.

IMPORTANT -- The problem is to be worked in sections. Each section must start on a new page of your solution. In addition, a summary page with a diagram 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.

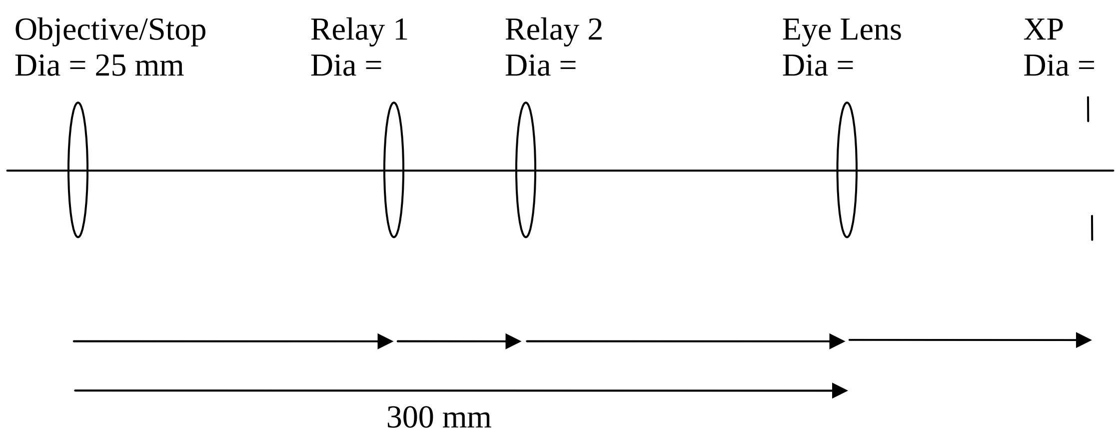
NAME ______________________________ Cover Sheet for Solution

Section A and B (also show intermediate image planes)



Section C – Summary comments

Section D (also show intermediate image planes)



YNU Method

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