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

Homework Set 12 Fall, 2011

Assigned: 11/17/11 Lecture 26
Due: 11/29/11 Lecture 28

12-1) A light source is to produce a spot of light on a distant wall. A 250 mm focal length lens with a diameter of 50 mm is to be used. The light emitting source is 4 mm in diameter (consider this to be the diameter of a flat source), and the wall is 25 m away.

a) This extended source is “collimated” by placing the source at the front focal point of the lens. What is the total spot size illuminated on the wall?

b) The lens is now used to image the source directly onto the wall. What is the resulting source size?

c) The source produces a total output power of 10 Watts. Using the imaging configuration of Part b), what is the irradiance on the wall?

12-2) The peephole from the earlier problem was designed to be fully vignetted over a +/- 45 deg FOV. The system specifications were found to be:

f1 = -3.83 mm
t1 = 25 mm
f2 = 28.83 mm
Peephole magnification = 0.133

Second element to eye separation = 25 mm
Eye pupil diameter = 4 mm

Because the second lens was found to have a diameter equal to that of the eye, the peephole was unvignetted only on axis. It has zero unvignetted field of view.

Determine the required lens diameters so that the peephole now has some unvignetted field of view with the same fully vignetted field:

Fully vignetted field of view of +/- 45 deg
Unvignetted field of view of +/- 30 deg

12-3) A slide projector is to project a 24 x 36 mm format onto a 1.2 x1.2 m screen at a distance of 10 m. Design a condenser and projection lens system to accomplish this.

The light bulb given to you by the project engineer has a filament size of 8.0 x 7.8 mm.

Make your design as practical as possible; for example, there must be a spacing between the condenser and the slide. Consider heat management. Make the system as light efficient as possible. Use an f/1 condenser lens, and determine the focal lengths and f/#'s of the components.

Include all the first-order information required to specify the system. Sketch the layout.

Do this problem first using a spherical concave mirror behind the source. After completing this baseline design, consider how the design would change if a faceted parabolic reflector was used. The diameter or clear aperture of the reflector should be about 40 mm.

12-4) An afocal adapter can be used to change the field of view seen by the detector/film in a camera with a given camera lens. A Galilean or reverse-Galilean telescope is simply placed in front of the camera lens to change the FOV. The afocal adapter is specified by its magnifying power MP, and this use of MP is the same as for a visual telescope.

If the focal length of the original camera lens is f_C, what is the focal length of the combination of the afocal adapter and the camera lens? You are required to provide a derivation of this result. Hint: Sketch the marginal ray path through the system with and without the adapter and use the definition of focal length (assume an object at infinity).

12-5) Design a compact 10X25 Gregorian telescope. The Gregorian telescope provides an erect image and consists of two concave mirrors followed by an eyepiece to produce an afocal system. An important design feature of a mirror-based telescope is its obscuration ratio. This ratio characterizes the fraction of the light entering the telescope that is blocked by the secondary mirror:

$$\text{Obscuration Ratio} = \frac{\text{Area of the Secondary Mirror}}{\text{Area of the EP Ignoring the Obscuration}}$$

Since the system stop is often at the primary mirror (as it is in this design), the obscuration ratio gives the reduction in light collection efficiency of the primary mirror. Remember that since the central portion of the primary mirror is obscured, there is no penalty for placing a hole in the center of the primary mirror to get the light out the back of the telescope and into the eyepiece.

An aperture is placed at the front of the telescope to define the diameter of the telescope tube. This aperture is physically located at the same plane as the secondary mirror. This aperture is not the system stop. The secondary mirror is often attached by a mechanical "spider" to this aperture. We will assume that this mechanical spider has no area.

<u>Section A</u>

Provide the first-order design of a Gregorian Telescope with the following specifications:

Magnifying Power	MP	10X
Field of View	FOV	+/- 2 deg
Primary Mirror		
Focal Length	f_P	45 mm
Diameter	D_P	25 mm
Stop is located at the primary mirror		
Obscuration Ratio		50%
Eye Lens Diameter	D_E	10 mm
Overall System Length	L	100 mm
(from the secondary mirror or mounting aperture to the eye lens)		
Unvignetted		
Object at Infinity		

For vignetting calculations, the element diameters must be at the minimum size to satisfy the condition for no vignetting. In other words, the entire diameters of the primary mirror, secondary mirror, field lens and eye lens must be used.

Determine the following:

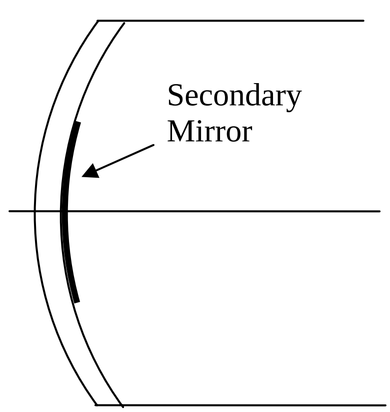
Primary Mirror:	Radius of Curvature	R_P
	Minimum Hole Size	D_H
Secondary Mirror	Radius of Curvature	R_S
	Diameter	D_S
Field Lens	Focal Length	f_F
	Diameter	D_F
Eye Lens	Focal Length	f_E
Aperture	Diameter	D_A
Exit Pupil	Diameter	D_{XP}
Eye Relief	(Eye Lens to XP)	ER
All Spacings		

For determination of the hole diameter in the primary mirror, you may assume that the primary mirror has zero thickness. A good check of the design is that the hole diameter must be smaller than the secondary mirror diameter.

The field lens is located at the second intermediate image plane. Please use the variable names as defined above. The system drawing on the solution page may also help in defining the system.

Section B

A Maksutov variation to the Gregorian telescope uses a thin meniscus glass shell to form the secondary mirror. This shell covers the entire entrance aperture of the telescope and eliminates the need for the mechanical spider or other mount for the secondary mirror. The central portion of the second surface of the shell is aluminized to produce the secondary mirror. In one option, both surfaces of the shell have a radius of curvature equal to that of the secondary mirror. A second option is to use a concentric shell.



For the purposes of this discussion, assume a 2 mm thick shell of BK7 glass (n = 1.517) with both surfaces having a radius of curvature equal to that of the secondary mirror.

Discuss the effect of this glass shell on the design obtained in Section A. Assume that the mirror curvatures and mirror spacing remains fixed. What changes would be needed to the eyepiece to obtain a telescope of the desired MP. This is a discussion problem only – do not redesign the telescope or the eyepiece.

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.

IMPORTANT -- 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.

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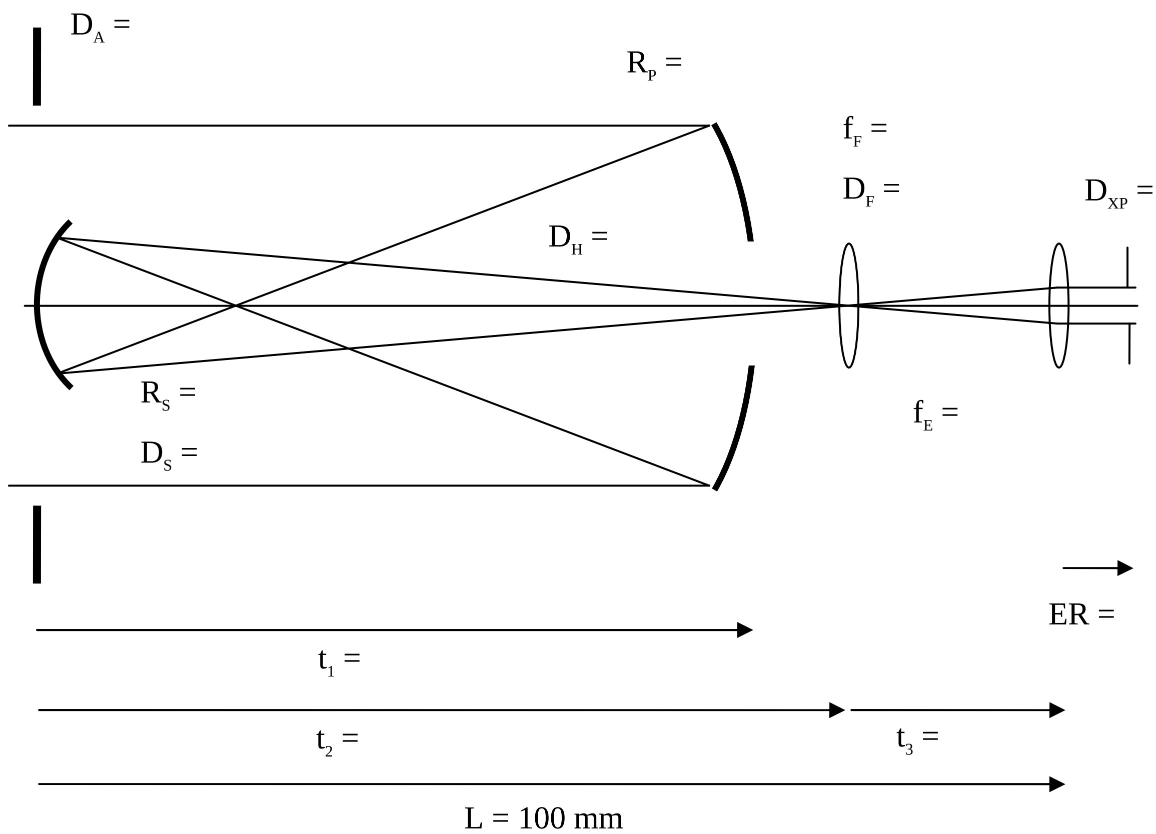
NAME ______________________________ Cover Sheet for Solution

Section A



Section B – Summary of Discussion

YNU Method

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