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

Homework Set 3 Fall, 2011

Assigned: 9/6/11 Lecture 5
Due: 9/13/11 Lecture 7

3-1) A 50 mm focal length thin lens in air is used to image a 250 x 250 mm object onto a 10 x 10 mm detector. What is the overall object-to-image distance? Do both the exact solution as well as by reasonable approximation.

3-2) For a thin lens in air, derive an expression for the overall object-to-image distance D as a function of the focal length and the magnification.

a) Plot D vs. m for a positive thin lens.
b) Plot D vs. m for a negative thin lens.
c) Note that for a given object-to-image distance D, there are two possible values of magnification. Determine these two values of m in terms of D and f. Show that these two magnifications are reciprocals, i.e. $m_1 = 1/m_2$.
d) For a positive lens with f = 100 mm, sketch the two scenarios for D = 600 mm.

3-3) You have a 100 mm focal length thin lens. For each given object position determine the image position and the image magnification. Note whether the object and image are real or virtual. The object and image locations are measured relative to the lens.

z = -10000 mm
-500 mm
-200 mm
-150 mm
-110 mm
-90 mm
-50 mm
-25 mm
50 mm
100 mm
200 mm
500 mm
10000 mm

3-4) Two stars are separated by 10 arc sec. What is the separation of the star images in the focal plane of a telescope/camera with a focal length of 1000 mm?

3-5) The following two methods determine the focal length of a positive lens by using two pairs conjugate locations. In both cases, real objects and images are required (the object to image distance must be larger than 4f).

a) Bessel's Method uses the two reciprocal magnification positions for a fixed object-to-image distance D. The lens is translated between a fixed object and a fixed viewing screen. Two positions of the lens will form an image on the viewing screen (reciprocal magnifications). The separation between these two lens positions is L. Derive the following expression for the focal length in terms of D and L:

$$f = \frac{D^2 - L^2}{4D}$$

b) In Abbe's method, the image of an object is formed on a viewing screen. The object position z_1 and image magnification m_1 are measured. The object is then moved and the new object position and image magnification z_2 and m_2 are measured. Derive this expression for the focal length as a function of z_1, z_2, m_1 and m_2:

$$f = \frac{z_1 - z_2}{1/m_1 - 1/m_2}$$

3-6) A 1 cm diameter detector is used to image a scene at infinity. What is the angular field of view (FOV) when using a lens with the following focal lengths: 10 mm, 25 mm, 50 mm, 100 mm, 200 mm, 1000 mm? Assume a thin lens, and report the FOV in degrees. The center of the detector is aligned with the optical axis of the lens.

3-7) Fill in the missing entries for the conditions given. The distances are Gaussian distances (measured from the respective principal planes).

f_F	f'_R	z	z'	m
-100	100	-200		
-100	100	-50		
-100	100		-200	
-100	100			0.25
-100	-100			-1.0
-100	-100	200		
100	-100	-100		
100	-100		100	
100	100			3.0
100	100		-50	