A525 - Problem Set # 2

September 15, 2008 Due: September 22, 2008

The homework assignments will be used as part of your final grade. Please work on this problem set by yourself.

1) A plano-convex lens is flat on one side and convex on the other. Suppose you have a lens with n = 2.1 and a diameter of 10 cm. The curved side of the lens is spherical. A 9 cm diameter aperture (aperture stop) is placed immediately in front of the lens to define the entrance pupil of the lens. The desired focal length is 15 cm.

   a) Estimate the radius of curvature of the convex side of the lens using the lensmaker's equation.

   b) Assume the thickness (vertex to vertex distance) is 1.0 cm; use the Ray-Trace program to make a system plot and spot diagram in the focal plane for a source located at infinity on the planar side. What is the back focal distance (distance from the vertex of the last optical element to the best focus)?

   c) Give the rms spot size for a source on-axis, and one degree off-axis.

   d) Vary the eccentricity of the curved surface to minimize the rms spot size. What eccentricity does this? Give the rms spot size for the on- and off-axis cases.

   e) Show spot diagrams for the on- and off-axis cases for part d).

   f) Do the same calculations (parts b, c, d, and e) for the case in which the source is on the curved side (a convex-plano lens).

   g) Which would you say is the better lens for the spherical case? Which is better when the eccentricity is allowed to vary?

2) We will now to consider a doublet which will accept light from a distant source (far-field). The design is a follows. We have two 10-cm diameter lenses which have the same focal length. They are placed 4 cm apart and have a 9-cm stop place midway between them (see Figure 1). We would like the focal length to be about 15 cm (it need not be exact – so you can use the back focal distance as the focal length). Assume that n = 2.1 for both lenses.

   a) From your experience with 2 lenses systems (problem set #1), compute the focal length of the individual lenses.

   b) Assume that we have a pc – cp configuration, that is, the first lens is plano-convex and the second is flipped to be convex-plano. What is the radius of curvature of the curved side for each lens?

   c) Perform a ray trace of the system and compute the rms spot sizes for on-axis and one degree off-axis. Fill in a Table (like Table 1) with your results.

   We can do our first optimization by making the surfaces conical rather than spherical.

   d) Vary the eccentricity of the two curved surface to minimize the rms spot size on-axis. You will find the variation window handy to do this. Fill the table with results for on-axis and one degree off-axis.

   Change the surface back to spherical. We will now optimize the system by "bending" the lenses. From the lensmaker's equation we see that adding a constant to the curvature of both side of a lens does not change the focal length. Figure 1 shows that the first lens consists of surfaces 1 and 2 while the second lens is surfaces 4 and 5. In the variation window you can bend lens with a command like:

BE 1 2 0.2

which will add 0.2 to the curvature of both surface 1 and 2. You can set a range by using the "vary" command, e.g.

vary be 1 2 -0.2 0.2

will fill a column with bending values ranging from -0.2 to 0.2 for surfaces 1 and 2. By using the matrix run command you can bend both lenses simultaneously.

e) Bend the lenses to minimize that rms spot size, noting both the behavior on-axis and off-axis. Again, tabulate your results in the Table.

f) Show a system plot and spot diagrams for this system. What is the primary aberration for the off-axis case?

Finally we can again vary the eccentricity to do a further optimization.

g) Vary the eccentricity of the surfaces of the second lens to minimize the rms spot size on-axis. Fill the table with results for on-axis and one degree off-axis, and show your on- and off-axis spot diagrams. What is the primary aberration for the off-axis case?

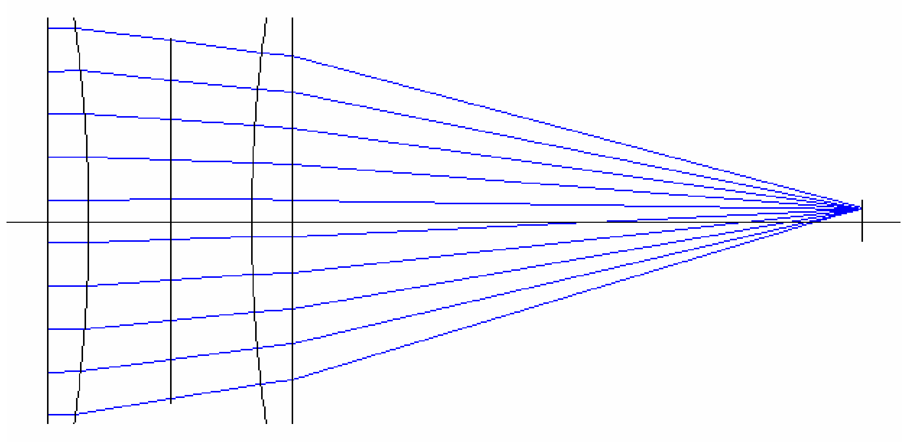

Figure 1: Schematic of doublet system.

Table 1: Ray-trace results for double lens system

	First Lens				Second Lens				rms spot size	
Case	r_1 (cm)	e_1	r_2 (cm)	e_2	r_1 (cm)	e_1	r_2 (cm)	e_2	$\theta = 0°$ (cm)	$\theta = 1°$ (cm)
1										
2										
3										
4										

Cases:

1. Initial design (spherical surfaces).
2. Case 1 with conical surfaces – eccentricity optimized
3. Case 1 with bending lens (spherical surfaces) – bending optimized
4. Case 3 with conical surfaces – eccentricity optimized