OPTI-502 **Optical Design and Instrumentation I** John E. Greivenkamp
Homework Set 9 Fall, 2011

Assigned: 10/27/11 Lecture 20
Due: 11/03/11 Lecture 22

Note that in many 502 homework and exam problems, only the magnitude of the magnification or MP is given. You need to determine the sign based upon the configuration.

9-1) A medium-format digital single lens reflex (DSLR) is to be designed using an image sensor in the DX or APS-C format. The sensor size is 24 x 16 mm.

a) The first task is to specify the focal length of the camera objective. The field of view for distant objects should be equivalent to a 35 mm film based camera with a 38 mm focal length lens. The 35 mm film format is 24 x 36 mm.

b) The next task is to determine the lens focus positions needed to cover a range of object positions from infinity to 500 mm. The camera lens will operate at f/4.

One criteria for good image focus is that the blur diameter due to defocus matches the pixel width on the sensor. For this problem, diffraction and aberrations are to be ignored. (Note that this criterion is very conservative, and significantly more blur may still produce good images.)

The pixels on the image sensor are 10.0 x 10.0 μm.

The first focus zone extends from infinity to its L_{NEAR}. The next zone starts at this position as L_{FAR} and continues to a new L_{NEAR}. The zones continue until the entire object range is covered. At each zone, give the required sensor location relative to the rear focal point of the lens. These values actually provide the amount of lens motion that is required to go from zone to zone (as the lens is actually moved, not the sensor).

This problem is best done by setting up a spread sheet. This also allows the various parameters to be varied to investigate system changes:

How does the number of required zones vary with
- Focal length?
- Blur?
- F/#?

9-2) Design a two-element reverse telephoto zoom lens:

Focal length range:	30 to 80 mm
Lens configuration:	Two-element zoom lens
	Reverse-telephoto configuration (negative-positive)
Element focal lengths:	f_1 = -50 mm
	f_2 = 50 mm

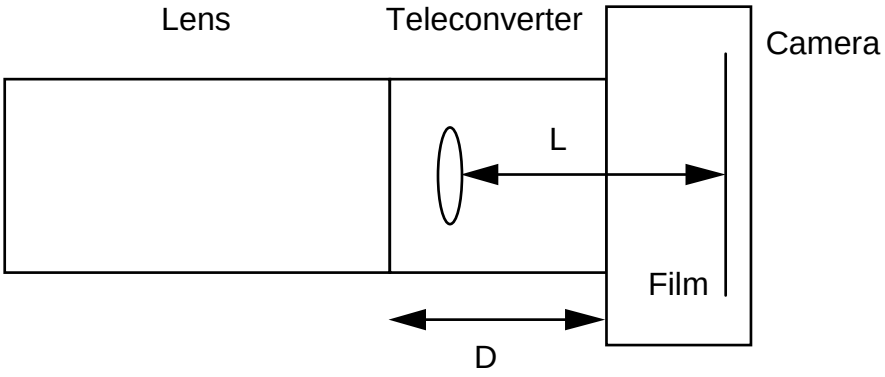
Assume an object at infinity. Both elements are thin lenses in air.

Provide the equations for the element separation and the back focal distance as a function of the system focal length. Also provide a table giving these two spacings and the total system length at the maximum and minimum focal lengths as well as at regular 10 mm increments of focal length (30 mm, 40 mm, 50 mm, etc.). Plot the lens positions relative to the image plane as a function of focal length (similar to the plot found in the class notes).

Note that the requirement for the two elements having equal but opposite focal lengths is given for computational ease. This is an arbitrary but useful choice.

9-3) A teleconverter is an optical component that is placed between your camera lens and camera to increase the focal length of the lens. Common varieties are 2X and 3X teleconverters. A 2X converter used with a 135 mm lens will result in an effective system focal length of 270 mm. A teleconverter consists of a fixed group of elements (consider it to be an equivalent singlet) in a tube of fixed length. It has no moving components and will work with any camera lens.

In addition to its focal length, the other two parameters you need to know about the teleconverter are the tube length D and the position of the singlet from the film plane L. Both of these are fixed and independent of the camera lens used.



a) Determine the focal length of an N-X teleconverter. Assume that the object is at infinity. Provide the necessary equations to show that the system focal length is increased by N and the image is still in the film plane. Show that D and L are related.

b) What happens to the f/# of the system with a teleconverter?

c) Provide a typical design for a 3X converter with D = 50 mm.

9-4) A 5X Keplerian telescope has a 200 mm focal length objective.
a) Determine the focal length of the eye lens and the overall telescope length.
b) If the stop of the telescope is the objective, what is the eye relief?

9-5) A pair of 6x30 binoculars (Keplerian) have 150 mm focal length objectives. What is the size of the exit pupil and how much eye relief is obtained?

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

9-7) Design a Keplerian telescope with a magnifying power of 10 and an eye relief of 11 mm. Specify the two focal lengths and the separation.

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?

9-9) A magnifier that is marked 10X is used to examine an object. The magnifier lens has a diameter of 10 mm, and the magnifier is used with a relaxed eye. This implies that the eye is focused at infinity, and that the virtual image produced by the magnifier is also at infinity.

a) The magnifier is first used as an eye loupe. The separation between the magnifier lens and the eye is 25 mm. What is the diameter of the half-vignetted field of view (object size in mm) seen through the magnifier? Assume that the eye has a pupil diameter of 4 mm.

b) The magnifier is now used as a magnifying glass by increasing the separation between the magnifier lens and the eye to 250 mm. What is the diameter of the half-vignetted field of view (object size in mm) seen through the magnifier? Once again, assume that the eye has a pupil diameter of 4 mm.

c) What do these results imply about the way a magnifier is best used?

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.