Lab 10: Gaussian Reduction
The Telephoto Lens

We will learn about Gaussian reduction by studying a common two-lens system, the telephoto lens. The principle of Gaussian reduction is to replace a system of lenses and mirrors with a pair of principal planes and an effective focal length that mimic the first-order optical properties of the original system.

The Telephoto Lens:

A telephoto lens consists of a positive objective lens, followed by a negative lens. The negative lens is placed inside the rear focal point of the positive lens. This combination has a positive focal length that is much greater than the focal length of the objective lens or the lens separation, t.

The following figure illustrates the telephoto lens:

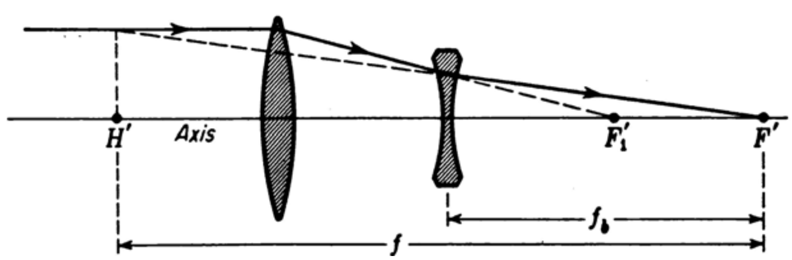

Fig. 10.1. Principles of the telephoto lens.
(from Fundamentals of Optics, Jenkins & White)

Note that when a positive lens is used to image distance objects (objects effectively at infinity), the image size is directly proportional to the focal length of the lens. As the focal length is increased, the image size increases. This has the effect of magnifying the image that falls within a fixed boundary (defined by the edges of a piece of film or a CCD electronic image sensor).

Two-Lens Paraxial Telephoto Design:

(Q1) Using the following two lenses, investigate how a telephoto lens works. Calculate the location of the system cardinal points, BFD, and focal length as a function of lens separation, t. Perform calculations to cover the range of focal lengths from 200-750mm:

f_1 = +200mm , lens location L1
f_2 = -150mm , lens location L2
lens separation ≡ t

Perform all of the calculations using a **computer spreadsheet**:

(1) Choose the effective focal length f_T (200-750mm in steps of 25mm)

(2) Calculate t
$t = f_1+f_2-(f_1*f_2/f_T)$ {take into account the sign of each focal length}

(3) Calculate the BFD
$BFD=f_T*(f_1-t)/f_1$

(4) Calculate the location of the front and rear cardinal points, relative to the two lenses (assume thin lenses, so that the front and rear vertices are located at the center of the positive and negative lenses, respectively).

(5) Report f_T, BFD, and the location of the front and rear cardinal points as a function of t.

Lab Exercises:

Investigate the telephoto system using the following two lenses :

Positive Lens : +200mm f.l.
Negative Lens : -150mm f.l.

Do the following for 5 different values of t, the separation of the two lenses:

- Choose 5 different values of t from the values you used in your Pre-Lab calculations.
- For each value of t, use the nodal slide to locate the **rear cardinal points** of the telephoto lens, referenced to the rear vertex, V*. Report the location of the rear cardinal points (H*, N*, F*), the focal length, and back focal distance BFD.
- Plot the measured values of focal length and BFD as a function of t.
- On the same graph, plot the calculated values of focal length and BFD as a function of t.
- Comment on how well the experimental and calculated values agree.