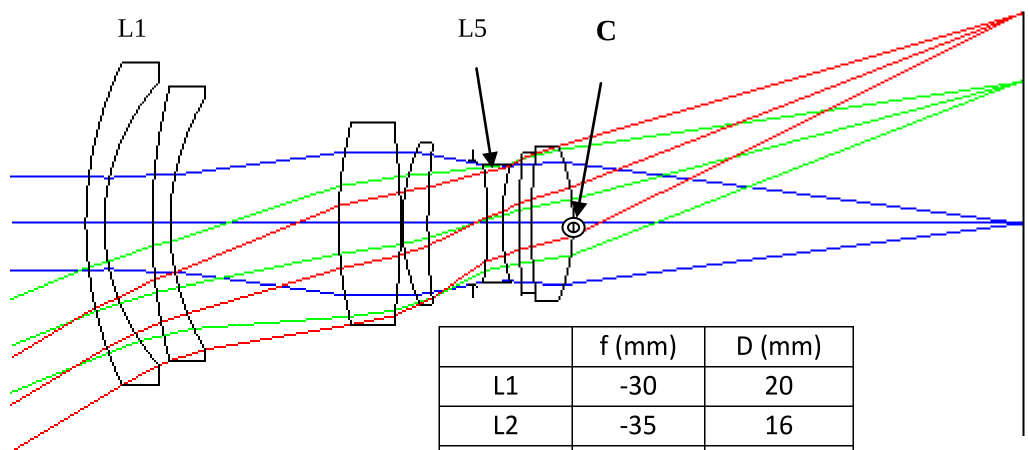
OPTI 421/521 – Introductory Optomechanical Engineering

Homework 2.

<u>Part 1. Short answer</u>

1) Consider a pair of BK7 Risley prisms with 2° wedge steering a laser beam. Starting from the case where the prisms are aligned in the zero deviation configuration, calculate the rotation for each element needed to cause the beam to deviate by 1° in the x direction without any deviation in the y direction. What is the maximum deviation possible for this pair?

2.) Consider the following objective lens. The system has 5 mm entrance pupil diameter and 20 mm EFL, 25 mm BFD (Back Focal Distance), and ± 31° FOV. The diameter and focal length of each lens element are provided.



	f (mm)	D (mm)
L1	-30	20
L2	-35	16
L3	28	11
L4	28	9
L5	-12	6
L6	20	8

a: Create a table that shows the image motion for 1 µm decenter motion of each of the 6 lenses.
b. Find the position of the nodal point for the objective.
c. Calculate the image motion for 1 mrad rotation of the objective about Point **C**.
d. Estimate the line of sight stability if each lens is stable to 1 µm and the system mounting allows 1 mrad rotation about C. Assume uncorrelated motions.

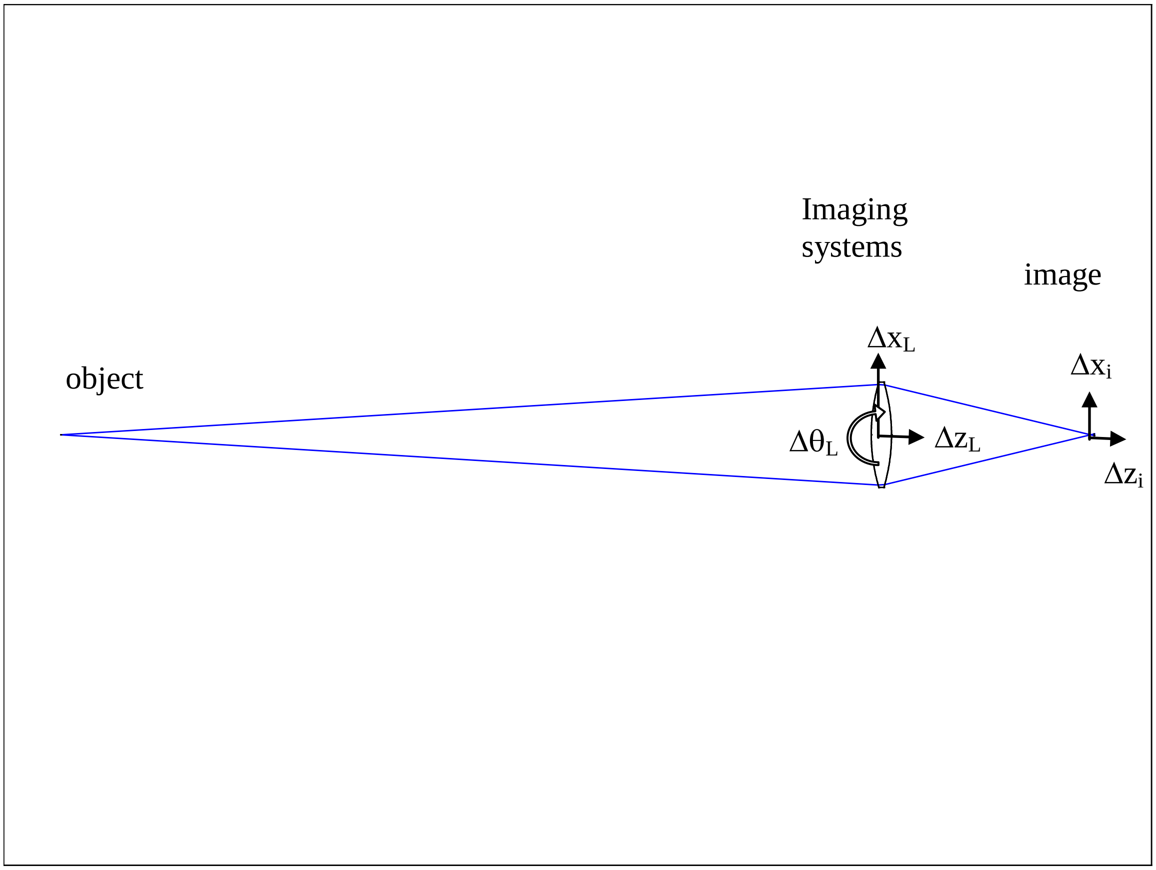
Part 2: Derivation

1. First order derivation: Lens motion

a) For the case of a thin lens, derive the relationships between image motion Δx_i, Δz_i and lens motion Δx_L, Δz_L , $\Delta\theta_L$ in terms of the system magnification *m*. Use your own sign convention, but be consistent!

b) Prove that the image shift Δx_i calculated above for Δx_L is consistent with the general relationship:

$$\boxed{\Delta x_i \cong F_n D_i \Delta\theta_i}$$



2. First order derivation: Mirror motion

Repeat a) and b) for the case of an image formed by a single mirror with focal length *f*.

Does your solution make sense for a flat mirror? What about a convex mirror (negative focal length)?

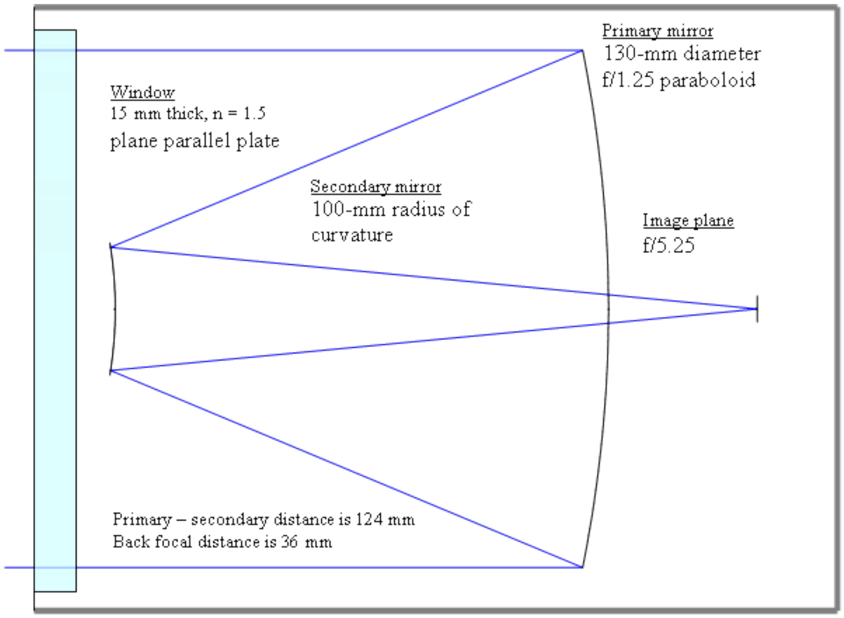
3. 521 students only (extra credit for 421 students)

Review the 2006 paper on image motion. Derive the relation that gives the stationary point for the general case, where the object is not at infinity. State all assumptions and show all steps.

Part 3. Engineering report: Boresight stability for a LIDAR system

Analyze the effect of motions on line of sight for a LIDAR collecting telescope.
Compute the net effect of all motions taking a root sum square of the individual contributions. Give the result in terms of image motion in microns at the focal plane, *and* in angle for object space.

Write your solution as a *brief* technical report. Submit the report separately from the other parts of the assignment. We will use peer reviews to evaluate the writing.



Stability of the telescope elements

Primary Mirror	5 µm rms lateral motion, 10 µrad rms tilt
Secondary Mirror	20 µm rms lateral motion, 20 µrad rms tilt
Window	50 µm rms lateral motion, 100 µrad rms tilt
Detector motion	3 µm rms lateral motion, 25 µrad rms tilt
System as a unit (entire assembly)	500 µm rms lateral motion, 25 µrad rms tilt

Part 4. Rules of Thumb

Decisions are made by efficiently by applying "rules of thumb" to make quick approximations. Throughout your career, you should make sure to collect these and know how and when to use them.

> As part of your homework assignments, you should review the relevant notes and find at least 3 useful rules of thumb. Report them in the following format. At the end of the semester, you will submit a compilation of useful rules of thumb.

Name for Rule: Small Angle Approximation
The Rule of Thumb: $\sin\theta \cong \theta$ where θ has units of radians
When is this used? This is used for small angles (< 0.2 radians)
Why is this useful? Application of this approximation greatly simplifies analysis and calculation.
Limitations: The percent error in the approximation is roughly $\theta^2/6 \times 100\%$ so the approximation is valid to < 1% for angles < 0.24 radians (14°) and is valid to 0.01% (100ppm) for angles < 1.4°.