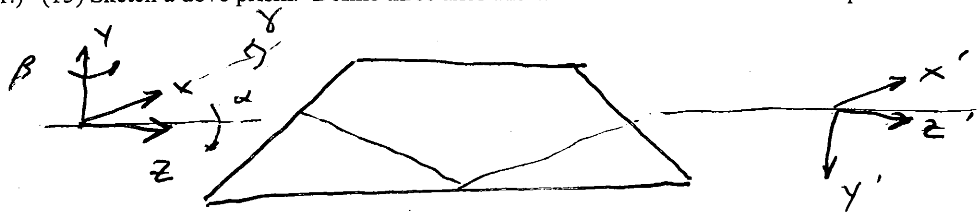
Introductory Optomechanical Engineering 421/521 – Fall 2015
Midterm 1 60 minutes, closed book, closed notes, no calculators

Name:

1.) (15) Sketch a dove prism. Define three axes and write the mirror matrix for this prism.

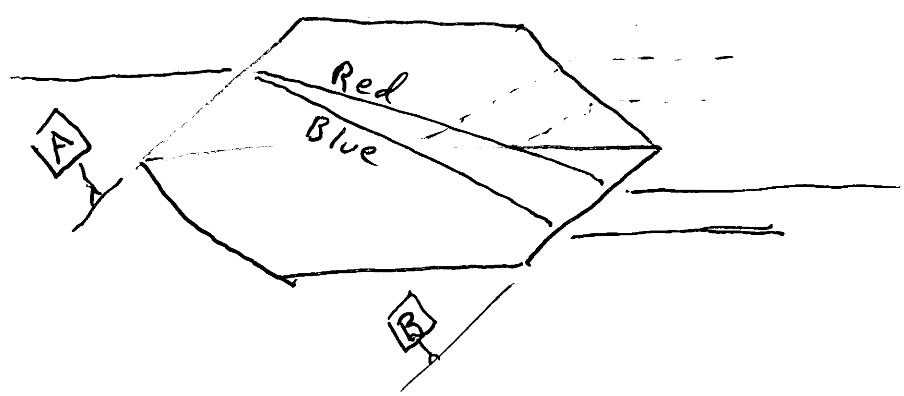


$$M = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Define roll, pitch and yaw on your sketch. Provide the approximate change of line of sight and image rotation for small angular motions about each axis:

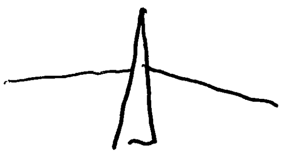
	Change in line of sight	Change in image rotation
Roll α	0	2α
Yaw β	0	0
Pitch γ	2γ	0

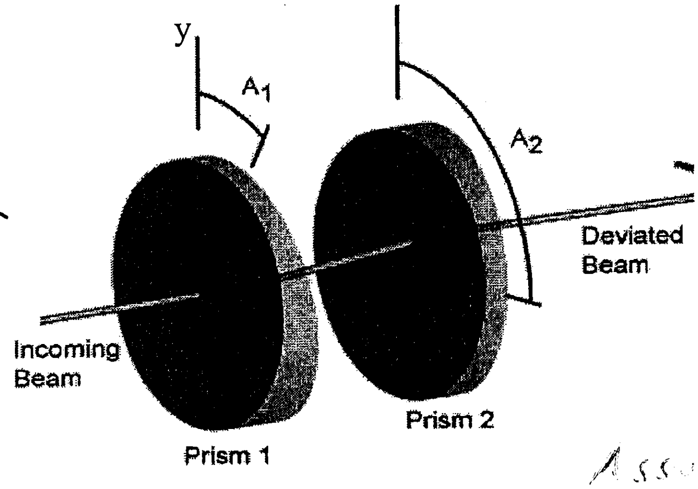
Draw the tunnel diagram for this prism and use it to show that this prism does not cause chromatic aberration.

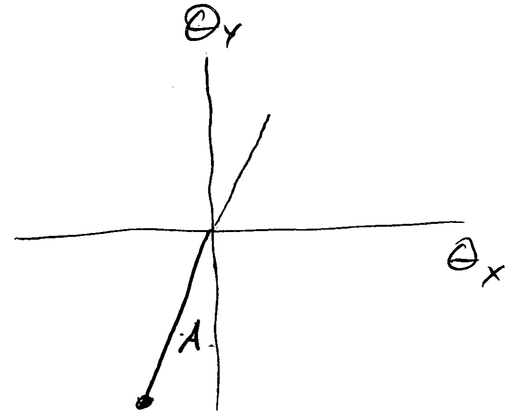


A is a plane parallel to B. resulting deviation angle is same ~~for~~ for red and blue. They both are not changed by a plane parallel plate

2) (15) Consider the following pair of Risley prisms, each with 40 mrad wedge. The angles are defined as below where A1 is the clocking angle of the first prism, defined by the "thin" side, with respect to the y axis. A2 is likewise for the second prism.







Assume $n \cong 1.5$

We wish use the prisms to make a linear scan of a laser beam in the y direction.

A) What is the maximum deviation angle possible from this system?

Each prism has deviation $(n-1)\alpha \cong 20$ mrad

Maximum for the pair is 2×20 or 40 mrad

B) Write the general equations that provide the deviation in each direction θ_x and θ_y as functions of A_1 and A_2

$A = 0,\ \theta_y = -20,\ \theta_x = 0$

$$\theta_x = -20 \cdot \sin A_1 - 20 \sin A_2$$
$$\theta_y = -20 \cos A_1 - 20 \cos A_2$$

C) Starting from the condition where the deviation is zero. Provide the rotation rate of each prism that makes a linear scan of the beam in the y direction at 1 mrad/second.

$$\theta_x = 0 = -20 \sin A_1 - 20 \sin A_2$$
$$\sin A_1 = -\sin A_2 \qquad \boxed{A_1 = -A_2} = A$$

$$\theta_y = -20 \cos A \times 2 = -40 \cos A$$

$$\theta_y = 0 \text{ for } \cos A = 0,\ A = 90^\circ$$

$$\dot{\theta}_y = 40 \sin A\, \dot{A} \qquad \text{at } A = 90 \ \sin A = 1$$

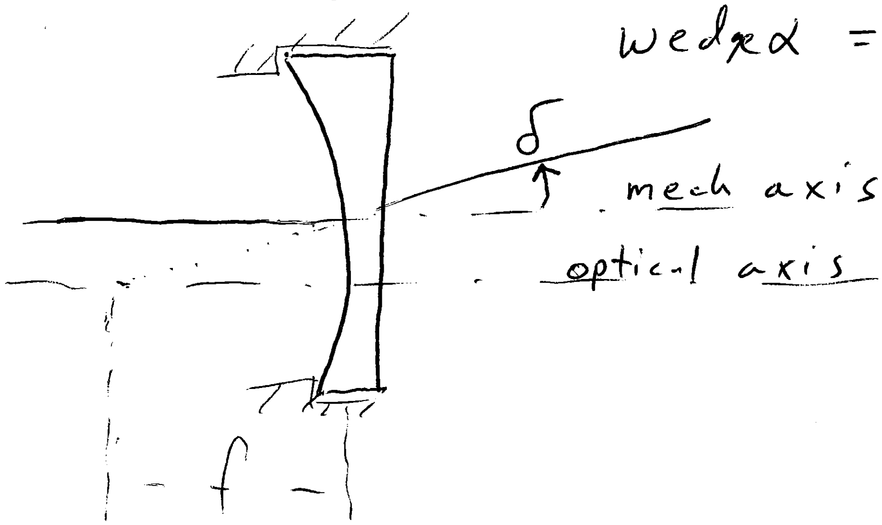
$$\dot{\theta}_y = 40 \dot{A} = 1 \text{ mrad/s} \qquad \dot{A} = \frac{1}{40} = 0.025 \ \text{rad/sec}$$
$$40 (\text{mrad}) \cdot \dot{A} = 1 \text{ mrad/s}$$

3) (10) Consider a 25 mm diameter, -250 mm focal length plano-concave lens was made with 25 μm ETD. Assume $n = 1.5$, so R = 125 mm (concave).

Consider two cases, **make a sketch** for each:

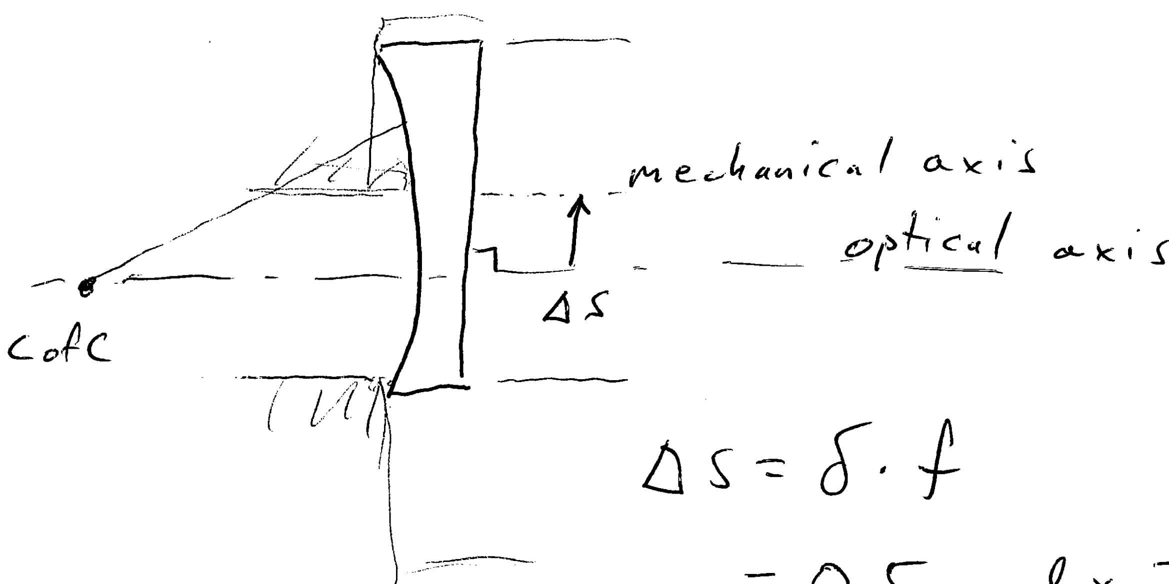
A) Assume the lens is mounted using the outer mechanical surface. Determine the angular deviation of light due to the wedge in the lens.

$$\text{wedge } \alpha = \frac{25\,\mu m}{25\,mm} = 1\ mrad$$



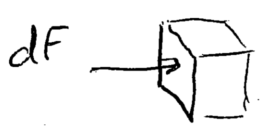
$$\delta = (n-1)\alpha$$
$$= 0.5\ mrad$$

B) If the lens is mounted such that the optical axis (defined by the two optical surfaces) is placed on the system axis, then the deviation will be zero. Determine the lens decenter (as defined by the outer edge) for such alignment.



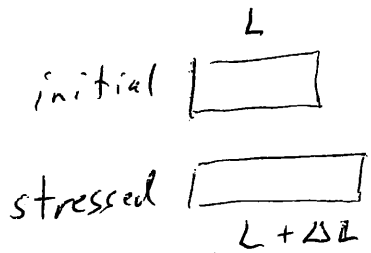
$$\Delta s = \delta \cdot f$$
$$= 0.5\ mrad \times 250\ mm$$
$$= 125\ \mu m$$

4) (10) Provide a definition for normal stress and normal strain. Show the relations between these for elastic materials. Use these to derive the length change of a rod in tension.



Area dA

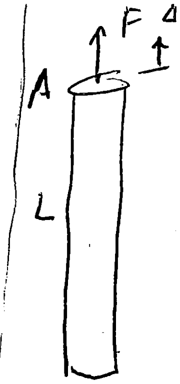
stress $\sigma = \frac{dF}{dA}$



strain $\varepsilon = \frac{\Delta L}{L}$

$\sigma = \varepsilon E$

E is elastic (Young's) modulus

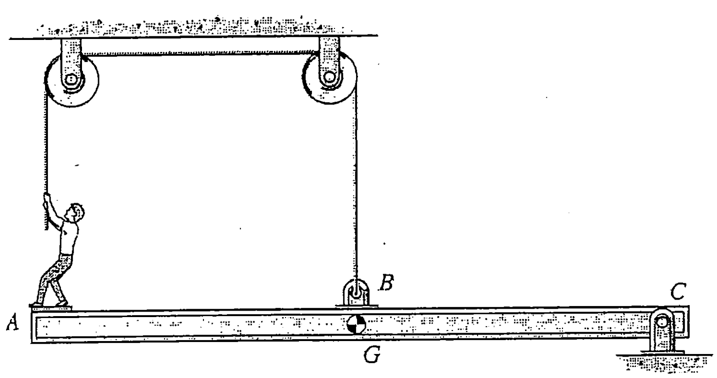


$\sigma = \varepsilon E$

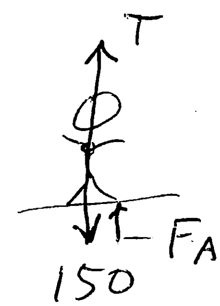
$\frac{F}{A} = \frac{\Delta L}{L} \cdot E$

$\Delta L = \frac{FL}{EA}$

5.) (10) Statics. Assuming the beam does not fall, what is the direction of the force applied to the beam at C? Solve for this force at C and the cable tension T assuming the man weighs 150 lb and the beam is 12' long, weighing 100 lb

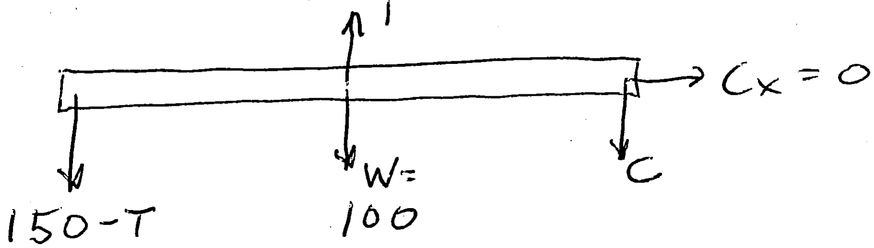


Man



$F_A = T - 150$

FBD acting on beam



$\Sigma M_B = 0$ by symmetry $150 - T = C$ C pulls down

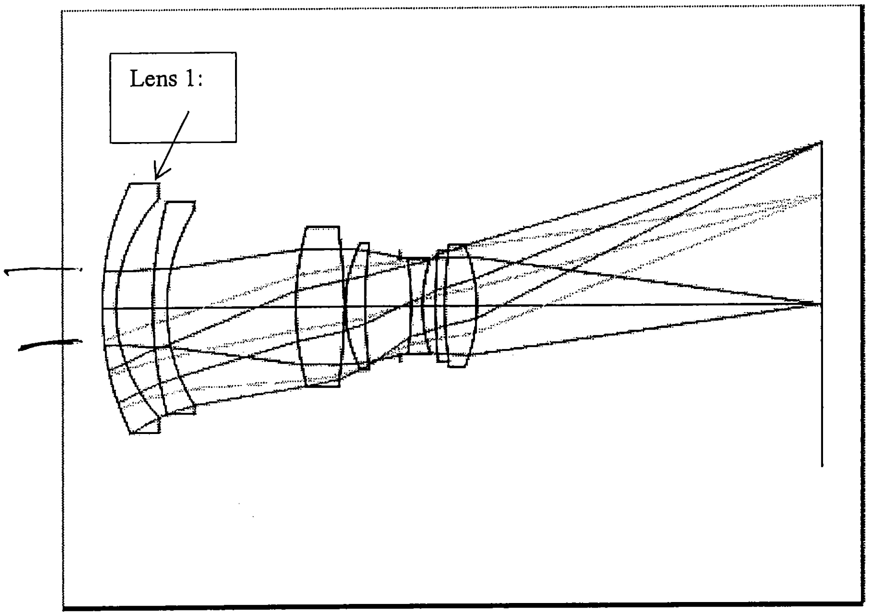
$\Sigma F_y = 0 = T - (150 - T) - 100 - C$

$= 2T - 250 - (150 - T)$

$= 3T - 400$

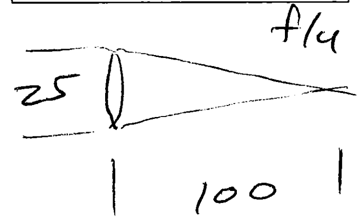
$T = 400/3 = 133$ lbs $C = 17$ lbs

6.) (15) Consider the following inverse telephoto lens, looking at an object far away



100 mm EFL
F/4 (Focal ratio = 5) 4
60° field of view

Lens 1:
90 mm diameter
R1 = 100 mm
R2 = 50 mm
Ct = 5 mm
n = 1.5
(-200 mm focal length)



Assume that Lens 1 is manufactured with 1 mrad wedge.

A) Determine the deviation of the light through the center of L1 due to its wedge

$$\delta = (n-1)\cdot\alpha = 0.5 \cdot 1 = 0.5\,\text{mrad}$$

B) If L1 is mounted according to its mechanical axis, determine the shift in image position, relative to the case for a perfect lens.

$$EPD: 100\,EFL \div 4 = 25\,\text{mm}$$

$$\varepsilon_i = B_i\,\Delta\theta_i\,F_n \qquad B = 25$$

$$\varepsilon_i = (25\,\text{mm})(0.5\,\text{mrad})\cdot 4 = 50\,\mu\text{m}$$

C) Determine the shift in L1 required to achieve proper alignment

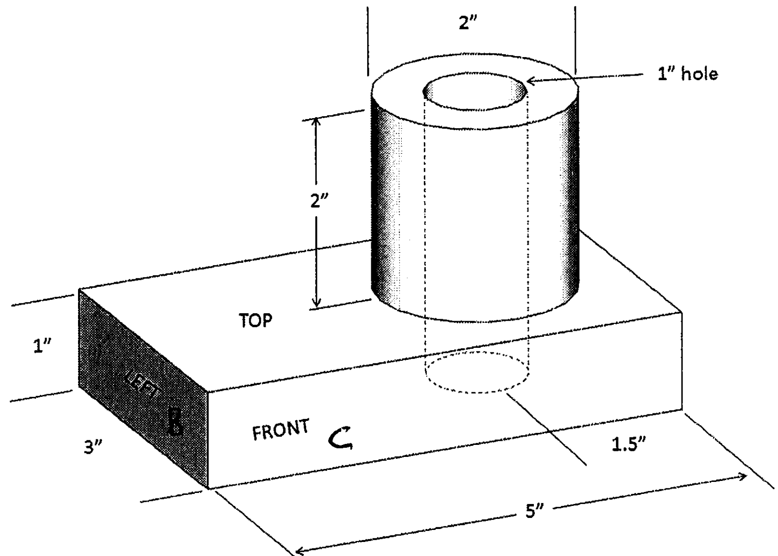
$$\Delta\theta_i = \frac{\Delta S_i}{f_i} = 0.5\,\text{mrad} = \frac{\Delta S}{200\,\text{mm}}$$

$$\Delta S = (0.5\,\text{mrad})(200\,\text{mm})$$

$$= 100\,\mu\text{m}$$

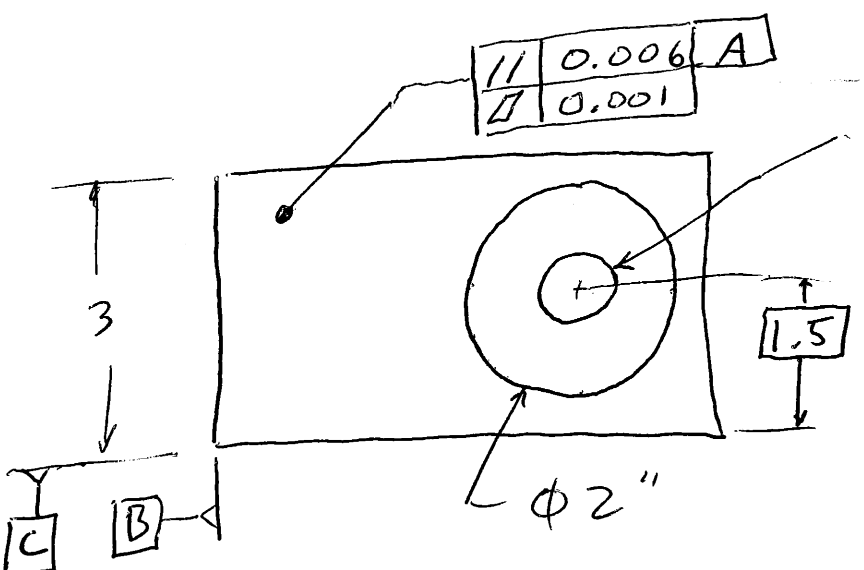
7.) (15) Sketch a 3-view orthographic projection of the following part, correctly showing all dimensions. (drawing in inches). Use appropriate drawing conventions to specify the following:

Top surface is flat to 0.001" and is parallel to the bottom surface to 2 mrad
The shape of the hole can depart from cylindrical by ±0.001"
The diameter of the hole must be correct to ±0.002"
The hole must be perpendicular to the bottom surface to 1 mrad
The true position of the hole must be correct with respect to the left and front surfaces to 0.001"



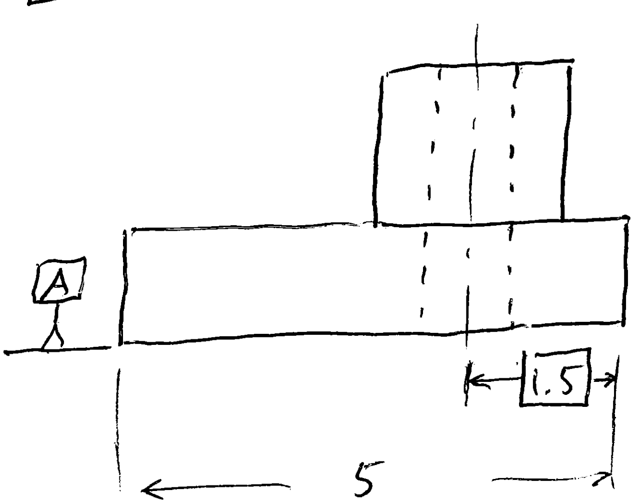
1 mrad × 3"
= 0.003"

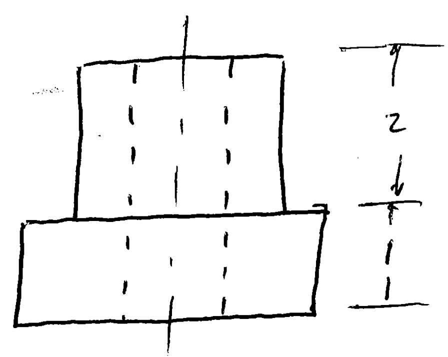
Tolerance zone
2 mrad · 3" = 0.006"



ϕ 1 ± 0.002

⌭	0.002			
⊥	0.003	A		
⌖	0.001	A	B	C





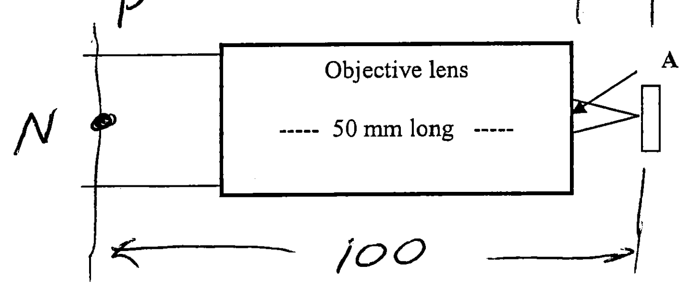
Units in inches.

8.) ((5) For the following case with a telephoto lens making an image of a distant object, determine the position of the nodal point and show it on the drawing. Show the position of the nodal point relative to point A:

10 mm entrance pupil diameter
F/10 focal ratio
20 mm BFD (Back focal distance from A to the focus)
5° FOV

|← 20

EFL = 10 · 10 = 100 mm



Nodal point N, 80 mm from A

9.) (5) What happens to the image if the lens above is rotated about point A by an angle of 1 mrad?

N moves 80 mm × 1 mrad = 80 μm

image moves 80 μm