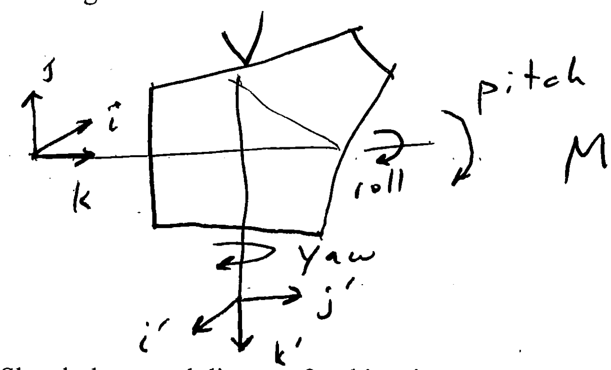
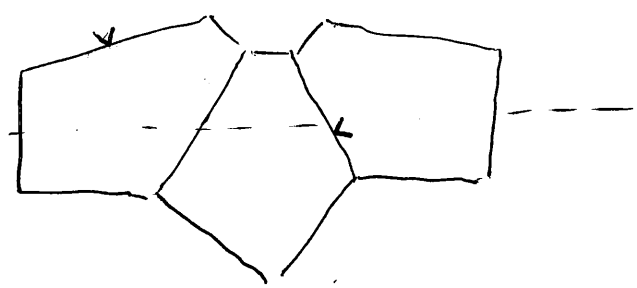
Optical Engineering 421/521 – Fall 2014
Midterm 1 50 minutes, closed book, no notes, no calculators

1.) (15) Sketch a roof penta prism. Define three axes and write the mirror matrix for this prism. Sketch its tunnel diagram.



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

Sketch the tunnel diagram for this prism.

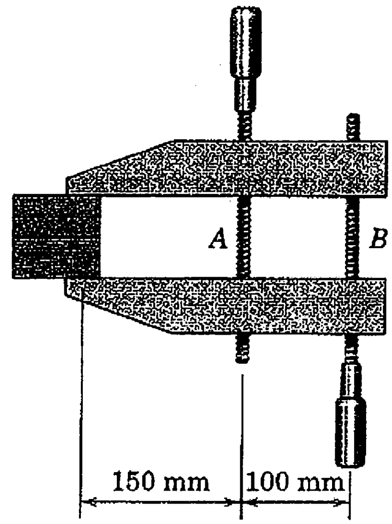


Define roll, pitch, and yaw on your sketch above. Provide the change in line of sight and image rotation for small rotations for each:

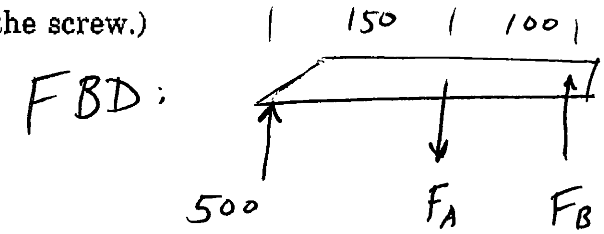
	Change in line of sight	Change in image rotation
Roll α	α	α
Yaw β	β	β
Pitch γ	0	0

2.) (5)

If the screw B of the wood clamp is tightened so that the two blocks are under a compression of 500 N, determine the force in screw A. (*Note:* The force supported by each screw may be taken in the direction of the screw.)



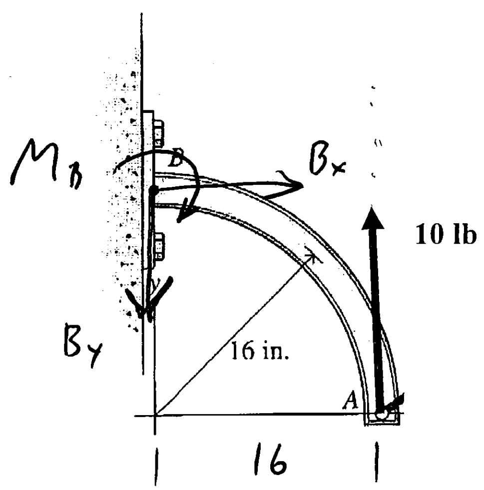
FBD:



$\Sigma M_A = 0 = -500 \cdot 150 + 100 \cdot F_B$ $\quad F_B = 750$ N

$\Sigma F = 0 = 500 + 750 - F_A$ $\quad F_A = 1250$ N

3) (5) Calculate the reactions at B for static equilibrium when a 10 lb vertical force is applied at A.



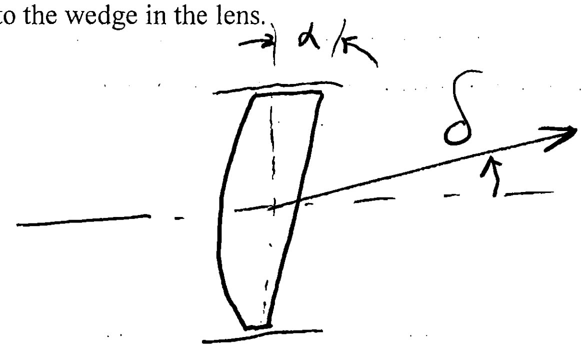
$B_x = 0$

$B_y = 10$ lb

$M_B = 10 \cdot 16 = 160$ in.·lb

4) (20) A 25 mm diameter, 500 mm focal length plano-convex lens was made with 50 μm ETD. Assume $n = 1.5$, so R = 250 mm. Consider two cases, **make a sketch** for each:

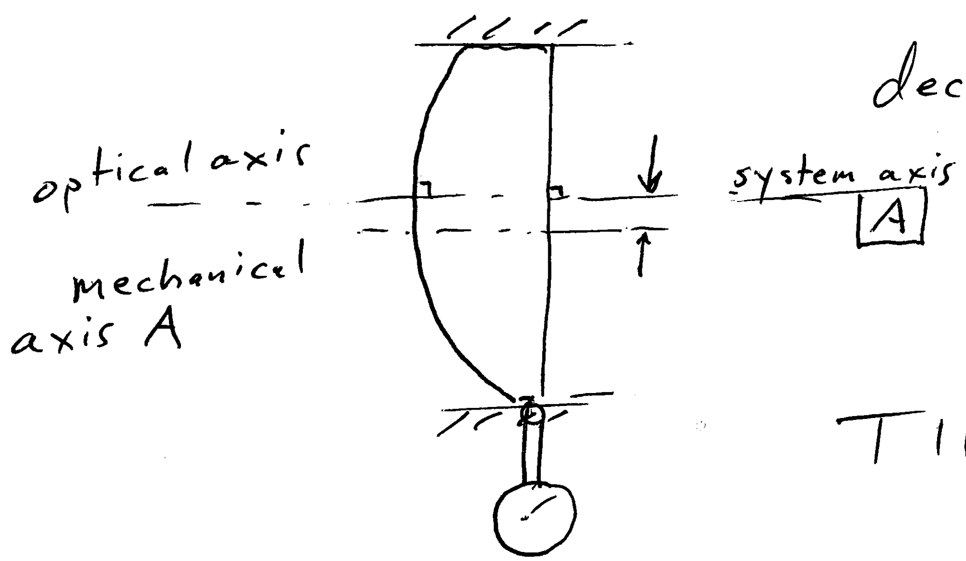
A) Assume the lens is mounted using the outer mechanical surface. Determine the angular deviation of light due to the wedge in the lens.



$$\alpha = \frac{ETD}{D} = \frac{50\,\mu m}{25\,mm} = 2\,mrad$$

$$\delta = \alpha \cdot (n-1) = 2\,mrad \cdot (0.5) = 1\,mrad$$

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. If the lens is rotated about this axis, determine the TIR (total indicator runout) of the outer edge.

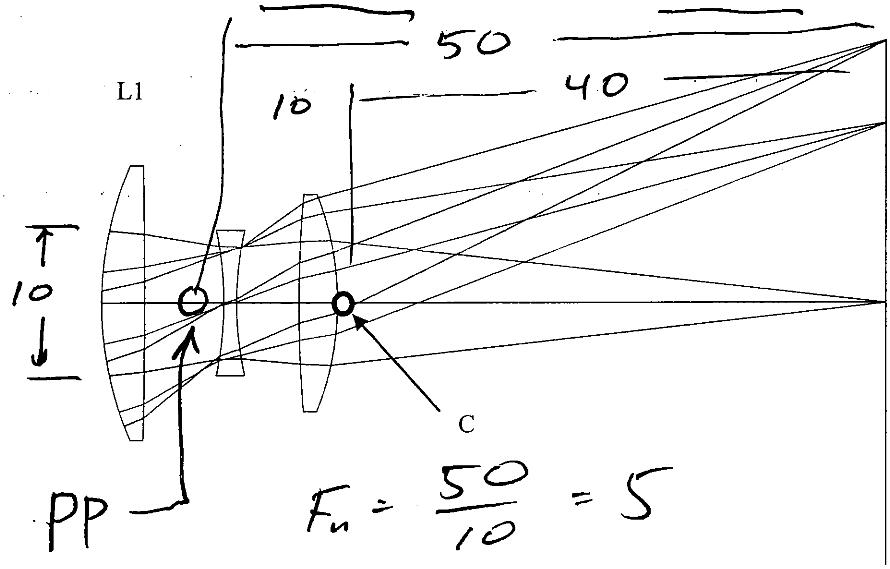


decenter $s = \delta \cdot f = 1\,mrad \cdot 500\,mm = 500\,\mu m$

$TIR = 2s = 1\,mm$

spin about A
indicator moves
$\pm 500\,\mu m$
$TIR = 1000\,\mu m$

5) (15) Consider the following lens system imaging and object at infinity.
The system has 10 mm entrance pupil diameter and 50 mm EFL, 40 mm BFD (back focal distance).



L1: 38 mm FL, 20 mm diam
L2: -20 mm FL, 10 mm diam
L3: 28 mm FL, 18 mm diam

	1	2	3
B_i/f_i:	10/38	8/20	8/28

B: 10, 8, 8

$F_n = \frac{50}{10} = 5$

$\varepsilon = B_i \theta_i F$
$= B_i \frac{\Delta x_i}{f_i} F$

A: For maintaining boresight stability, which element is most sensitive?

L2

B: For 1 μm decenter of L2, calculate the resulting image shift.

$\varepsilon = 8\text{ mm} \frac{1\,\mu m}{20\text{ mm}} \cdot 5 = \frac{40}{20} \cdot 1\,\mu m = 2\,\mu m$

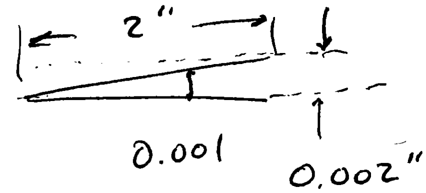
C. Determine the change in line of sight for 0.1 mrad rotation of the lens system about point C. Assume all of the lenses rotate together about this point, but that the focal plane is fixed.

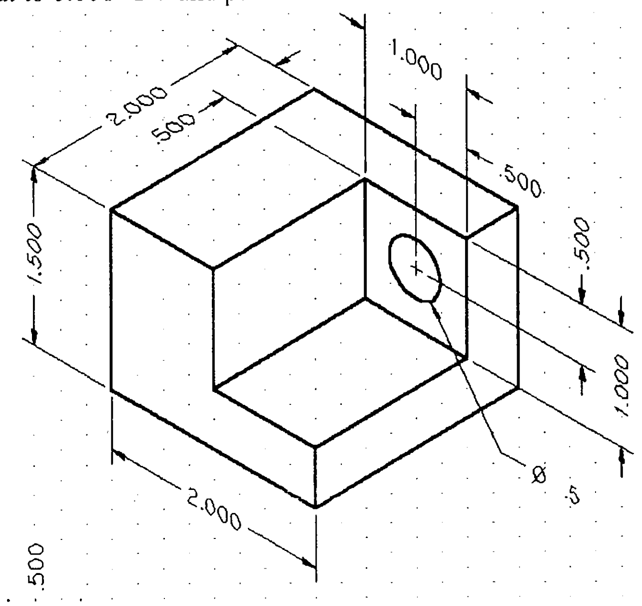
0.1 mrad × 10 mm = 1 μm image motion

50 mm EFL

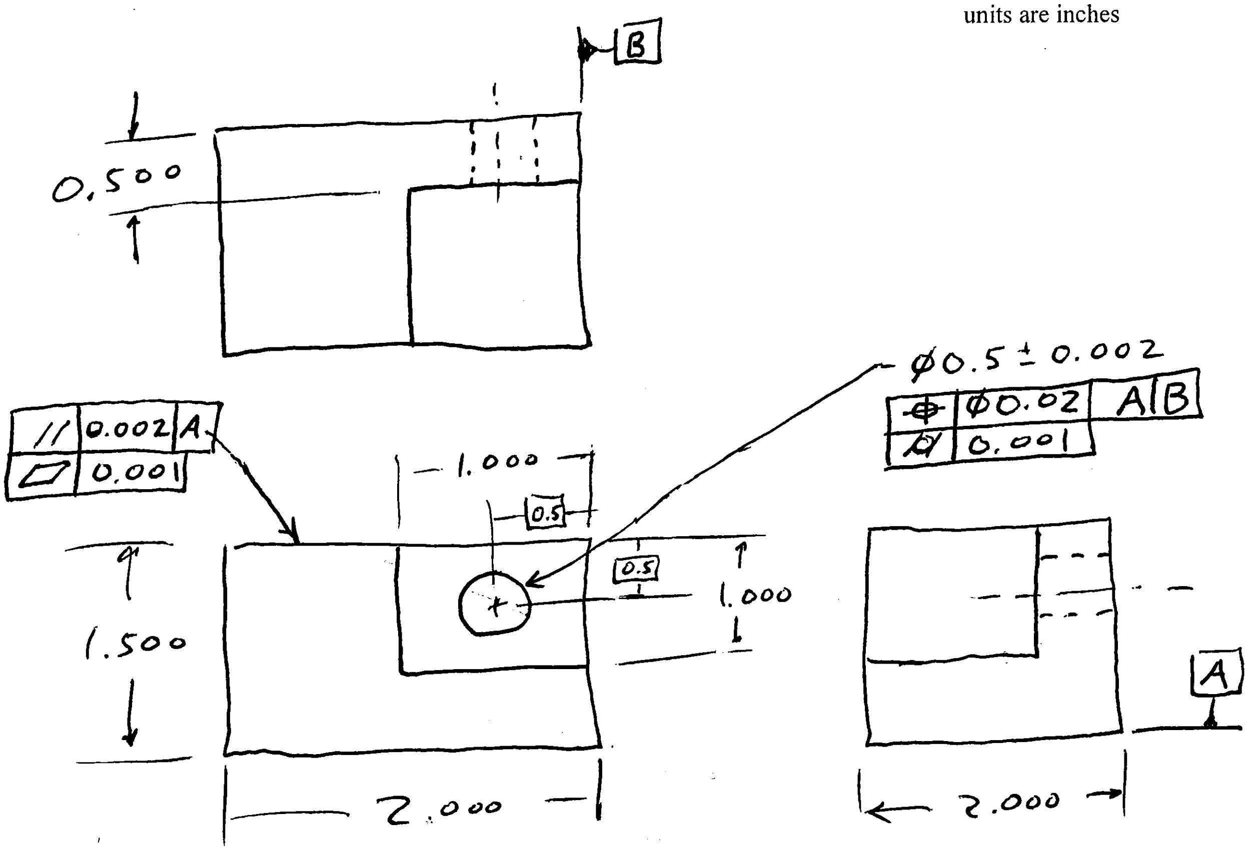
Object Space: $\Delta\theta = \frac{1\,\mu m}{50\text{ mm}} = 0.02$ mrad

6.) (20) Sketch a 3-view orthographic projection of the following part. Provide all dimensions.
Provide dimensioning that shows the hole with diameter tolerance of ±0.002", position tolerance of ±0.010", and cylindricity tolerance of 0.001"
Specify the top face to be flat to 0.001" PV and parallel to the bottom face to 1 mrad.





Material 6061-T6 aluminum
units are inches



7) (5) What is the name of the machine that would be used for making the part in the previous problem?

The mill

8) (15) Consider a 25 mm diameter meniscus BK7 lens with the following properties:

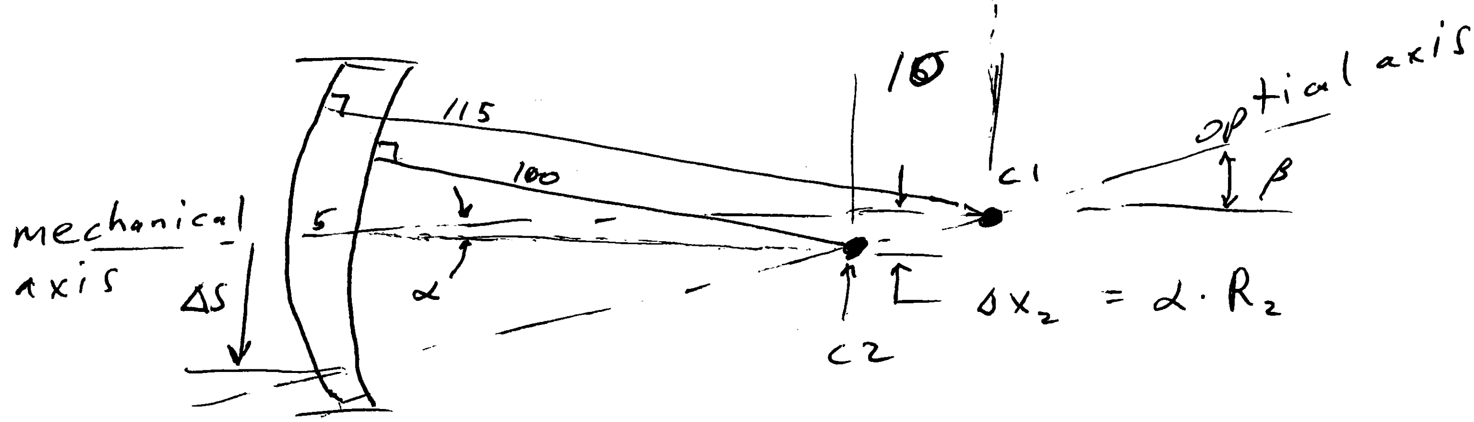
R1 = 115 mm convex

R2 = 100 mm concave

Ct = 5 mm

The lens is initially mounted using the convex surface and the outer edge to define tilt and decenter respectively. When the lens is rotated about this axis, the optical deviation of 0.1 mrad is measured.

Provide a sketch that shows the optical axis. Use this to show the decenter of the lens element required to eliminate the deviation.



$$\delta = 0.1 \text{ mrad}$$

$$\alpha = \frac{\delta}{(n-1)} = \frac{\delta}{0.5} = 0.2 \text{ mrad}$$

$$\Delta X_2 = \alpha \cdot R_2 = 0.2 \text{ mrad} \cdot 100 \text{ mm} = 20 \mu m$$

$$\beta = \frac{\Delta X_2}{10 \text{ mm}} = \frac{20 \mu m}{10 \text{ mm}} = 2 \text{ mrad}$$

$$\Delta S = \beta \cdot R = 2 \text{ mrad} \cdot 100 \text{ mm} = 200 \mu m$$