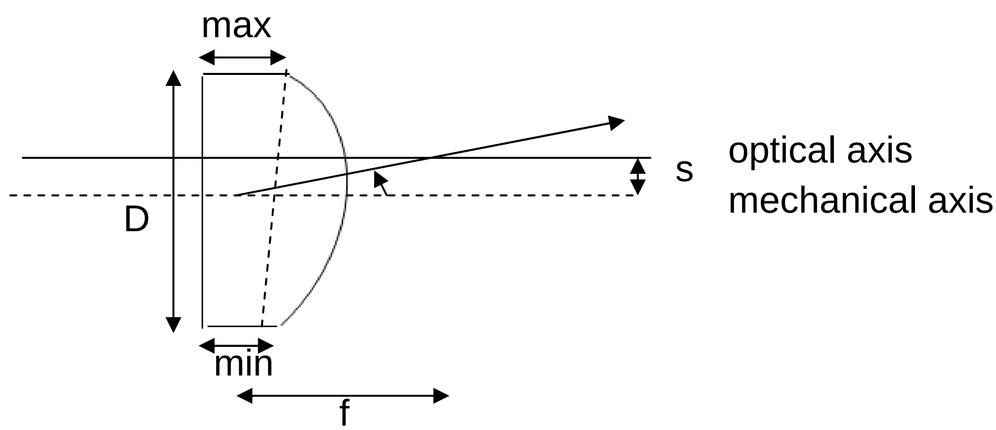
1. Consider a 50mm diameter plano-convex lens with 300mm focal length. For ETD of 0.1mm, determine wedge, deviation, decenter, optical axis, and mechanical axis. Show these on a sketch.
   Assume n=1.5

$$Wedge\,\alpha = \frac{\mathrm{ETD}}{\mathrm{D}} = \frac{0.1\mathrm{mm}}{50\mathrm{mm}} = 0.002\mathrm{rad} = 0.1145^{\circ}$$
$$Deviation\,\delta = \alpha(n-1) = (0.002\mathrm{rad})(1.5-1) = 0.001\mathrm{rad} = 0.0573^{\circ}$$
$$Decenter\,s = \delta f = (0.001\mathrm{rad})(300\mathrm{mm}) = 0.3\mathrm{mm}$$



*Note: Not drawn to scale

2. Consider the system below with 10mm entrance pupil diameter, 50mm, EFL, with object at infinity. Assume each lens surface is finished to 2 waves PV irregularity (at 587nm). Determine the degradation to the rms image size due to the lens surface irregularity.
   Assume normal incidence
   Indices found from sample Cooke Triplet in Code V (ok to use 1.5, but next time, look up proper values rather than always use RoT)

$$\varepsilon_i = 2\Theta(n-1)\cos(\phi)\alpha_i F_n$$
$$\alpha_1 = 9.5/18 = 0.5277$$
$$\alpha_2 = 9/18 = 0.5$$
$$\alpha_3 = 7.2/9.5 = 0.7578$$
$$\alpha_4 = 7/9.5 = 0.7368$$
$$\alpha_5 = 8/14.1 = 0.5673$$
$$\alpha_6 = 8.1/14.1 = 0.5744$$

$$n_1 = 1.620410$$
$$n_2 = 1.616589$$
$$n_3 = 1.620410$$

$$\varepsilon_{rms} = 11.008\mu m$$
$$\varepsilon_{rms} = 8.898\mu m\ (n = 1.5)$$

3. Consider the same optical design as 2), but use better lenses, finished to 0.1 waves PV (at 587nm). Estimate the contribution to rms wavefront error from the lens surfaces.
   Assume normal incidence

$$\Delta W_i = \alpha_i \Delta S(n-1)\cos(\phi)$$
$$\Delta W_{rms} = 0.0938\lambda = 0.055\mu m$$
$$\Delta W_{rms} = 0.0758\lambda = 0.044\mu m (if set n = 1.5)$$

4. Consider at 25mm beam splitter with refractive index inhomogeneity of ±0.00001. Determine the PV and rms wavefront variation due to the glass. For 0.5µm wavelength, calculate the Strehl ratio assuming this is the only error in the system.

$$\Delta W = t\Delta n$$
$$\Delta n_{PV} = \pm 0.00001 = |0.00002| = 20\text{ppm}$$
$$\Delta W_{\text{PV}} = (25\text{mm})(20\text{ppm}) = 500\text{nm}$$
$$\frac{\text{PV}}{rms} = 4$$
$$\Delta W_{rms} = 125\text{nm} = \frac{\lambda}{4}$$
$$\sigma = \frac{2\pi}{\lambda}\Delta W_{rms} = \frac{2\pi}{\lambda}\frac{\lambda}{4} = \frac{\pi}{2}$$
$$SR = e^{-\sigma^2} = 0.0848 = 8.48\%$$

5. A pitch polished aspheric mirror will typically have surface roughness of 20Å rms. This causes wide angle scatter. Calculate the total amount of scatter from one of these mirrors at 400nm light.

$$\Delta W = \Delta S(n-1)\cos(\phi)$$
$$n = -1 (mirror), assume \cos\phi = 1$$
$$\Delta W_{rms} = 2\Delta S_{rms} = 40\dot{A} = 4nm$$
$$\sigma = \frac{2\pi \Delta W_{rms}}{\lambda} = 0.0628 rad\,(\lambda = 400nm)$$
$$scattered light:$$
$$\sigma^2 = 0.003948 = 0.39\%$$