1. Achromatic Doublet **(5 pts)**

Design an achromatic doublet for a nominal focal length f = 200 mm for the center wavelength of the Na D doublet (λ = 589.3 nm) from 518:596 crown glass (n = 1.518, V = 59.6) and 617:366 dense flint glass (n = 1.617, V = 36.6). A positive lens is followed by a negative lens whose concave front face fits the convex back face of the L^+. What are the curvature radii $R_1 = -R_2 = -R_3$ and R_4 of the lenses to obtain the target focal length of the pair?

2. Propagated Modes in Optical Fiber **(4 pts)**

(a) Explain qualitatively, by sketching the geometry of a planar light guide, why there is a selection of transmitted modes in the angular directions of rays within the light guide.

(b) Using the geometric argument from the sketch, derive the resonance condition that determines the distribution of modes.

3. Standing Wave I **(4 pts)**

Use the complex representation to find the composite wave $E = E_1 + E_2$ that derives from

$E_1(x,t) = E_0 \cos(kx - \omega t)$ and $E_2(x,t) = -E_0 \cos(kx + \omega t)$.

4. Standing Wave II **(4 pts)**

The solution of problem 4 is the standing wave, $\vec{E}(x,t) = 2\vec{E}_0 \sin kx \cdot \sin \omega t$ where $\vec{E}_0$ points in the direction of $\hat{e}_y$. Derive the field $\vec{B}$ associated with $\vec{E}$ and draw a sketch of the two fields over one wavelength λ.

5. Dispersion Relation in Plasma **(3 pts)**

Hecht, Problem 7.29:

A plasma is a dispersive medium for EM waves with a dispersion relation described by $\omega^2 = \omega_p^2 + c^2k^2$ where ω_p is the plasma frequency. Derive the phase and group velocities, v_{ph} and v_g, in the plasma as functions of ω and ω_p and show that $v_{ph} \cdot v_g = c^2$.