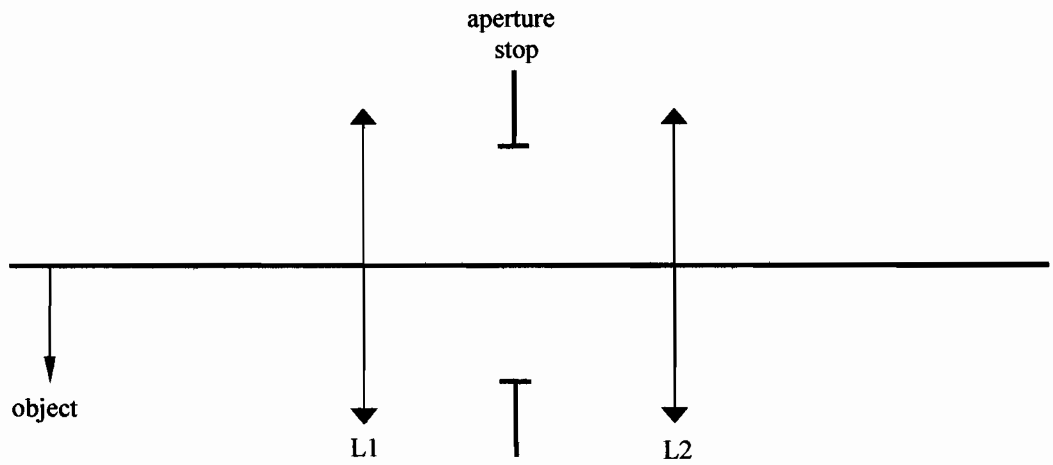
Physics Comprehensive Exam, 2006
Special Topic: Optics

Instructions: Do problems 1 and 2 and any 4 of the remaining problems. The problems have equal value.

1) Below is a diagram of a simple optical imaging system comprised of two thin lenses and an aperture stop. The lens' focal lengths are both 50 mm, their separation is 50 mm, and the 40 mm diameter aperture stop is placed symmetrically between them. Assume a 20 mm high object placed 50 mm in front of the first lens.



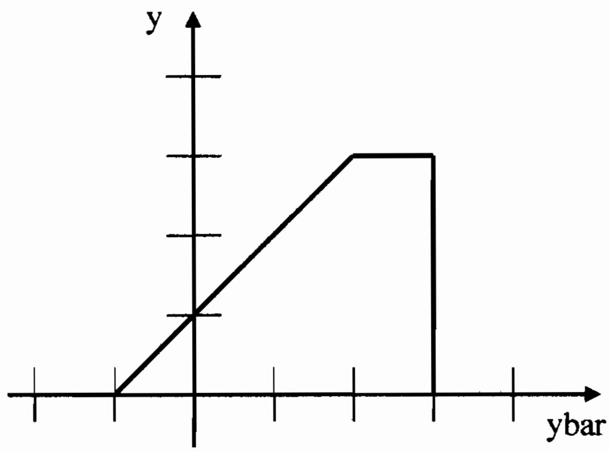
a) Use the ynu ray trace chart provided to trace the chief and marginal rays. Draw these rays on the diagram above.

b) Find the following information;
1. The optical invariant
2. The entrance and exit pupil locations and sizes
3. The effective focal length of the system

Surface #	Object	1 (Lens 1)	2 (Ap-Stop)	3 (Lens 2)	Image
$-\phi_j$					
t_j/n_j					
y					
nu					
y-bar					
$n\bar{u}$					

2) The diagram below shows a y-ybar diagram for thick lens of index n = 2. The system has an optical invariant of 0.01, with the following parameters;

Surface #	y	ybar
0 - Object	0	-1
1 – aperture stop	1	0
2	3	2
3	3	3
4 - Image	0	3



a) Find the following quantities; aperture stop diameter, transverse magnification, distances between surfaces 0 and 1, 1 and 2, 2 and 3, and 3 and 4
b) Mark on the diagram where the entrance pupil and principle planes lie. Where is the exit pupil located?
c) Make a scale drawing of the system and trace the chief and marginal rays. Indicate the position and diameter of the stop in the drawing.

3) Imagine a ray of light incident upon transparent, flat sapphire surface at angle θ_{inc}. The refractive index of sapphire is 1.76.
a) Sketch θ_{inc} vs. the refracted angle, θ_{refr}, for $0 \leq \theta_{inc} \leq 90$.
b) Assume now that sapphire is the incident medium and vacuum is the exiting medium. Again sketch θ_{inc} vs. θ_{refr}, this time indicating the critical angle. What is its value?
c) How would you expect these two curves to change if you replaced the sapphire with fused silica, whose refractive index is only 1.46? (No sketch here)

d) What, if anything, does the answer to part c) tell you about the chromatic dependence of light transmission through a dielectric interface?

4) Write down the transmission function for a simple transparent optical wedge and show that when it is illuminated with a monochromatic plane wave, the far field beam is deflected from its original path.

5) Suppose 2 plane waves interfere (at some angle with respect to each other) in a linear material. Field #1 is represented by electric and magnetic field vectors, $\mathbf{E}_1$ and $\mathbf{B}_1$ and field #2 is represented by electric and magnetic field vectors, $\mathbf{E}_2$ and $\mathbf{B}_2$. Let the Poynting vectors for each be given by:

$$\mathbf{S}_1 = \mathbf{E}_1 \times \mathbf{B}_1 \quad \text{and} \quad \mathbf{S}_2 = \mathbf{E}_2 \times \mathbf{B}_2$$

Show that, in general, the energy flow magnitude and direction **is not** determined by $\mathbf{S}_1 + \mathbf{S}_2$. Under what circumstances is the energy flow given by this vector sum?

6) What experiments are done to measure the spatial and temporal coherence of a source? Sketch them and show what the data might look like for a reasonably (spatially and temporally) coherent source. Estimate a value for the temporal and spatial coherence of the Sun. Coherence is usually given in terms of "length". How is this justified?

7) Suppose an optical resonator comprised of a flat mirror and a spherical mirror. Arrange these and choose values for the separation and radius of curvature so that the resonator will be most stable. What are the advantages of a stable resonator? Why would we ever choose an unstable resonator?