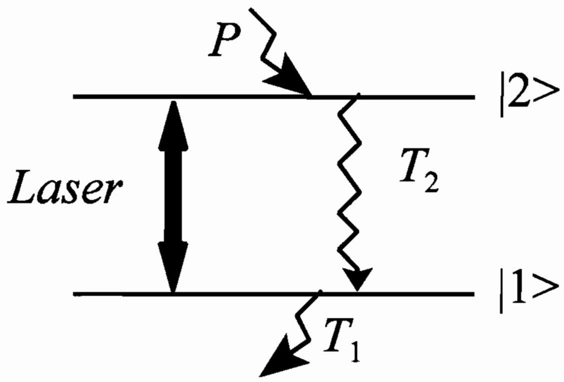
Direction: Work 3 out of the following 4 problems.

(1) **Laser Physics:** A free-pion laser consists of two mirrors cavity and the gain medium. The emission wavelength is $\lambda_L = \pi$ μm = 3.1415 μm and the stimulated emission occurs between the upper-level |2> and the lower-level |1> (as show below).



Let P be the pumping rate per gain center into the upper-level, T_2 = 1 μsec the lifetime of the upper-level (which decays only to lower-level)and T_1 = 1 nsec the lifetime of the lower-level. The cross-section of the laser transition is σ_{12} = p nanometers squared = 3.1415 nm^2 (note 1 nm^2 = 10^{-12} mm^2) and the density of the gain centers in the media is $\mathcal{N} = 10^{-14}$ mm^{-3}. The gain medium length is ℓ = 1 cm. The standing-wave laser cavity consists of a 100% reflector and output coupler with reflectivity $\mathcal{R}$= 0.95 and transmission $\mathcal{T}$ = 0.05 (where $\mathcal{R} + \mathcal{T}$ = 1.) The cavity length is L = 10 cm. The output coupler is a planar mirror and the 100% reflector has a radius of curvature of 20 cm.

(A) Ignoring all loses except for cavity losses at the out mirror, determine the necessary gain "g" (in units of gain per centimeter) that is necessary to achieve steady state or cw output.

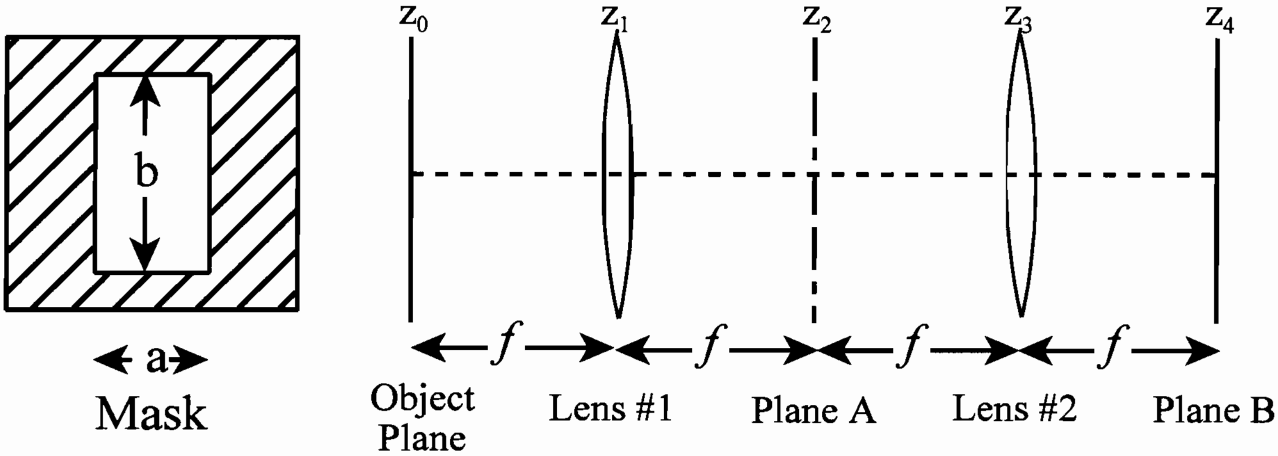
(B) Develop the rate equation for the inversion of the media with no laser field present based upon the simplified model pictured above. From this equation determine the necessary pumping P to reach the threshold gain.

(C) Assuming that you have unlimited energy to pump this laser, determine the minimum value for the reflectivity that the output coupler can have. The simplified model above has ignored all other level with the laser media. Discuss physically why in this limit, the parameter P must "saturate" to some maximum value.

(D) The laser operates in the fundamental Gaussian mode. Determine the size of the beam at both the planar output coupler and the curved 100% reflector.

(E) Determine the frequency difference between adjacent longitudinal cavity modes.

(2) **Imaging and Point Spread Functions:** Consider the optical system pictured below. The two lenses are identical having a focal length of f. The distance between the object plane, Lens #1, Plane A, Lens#2, & Plane B are all equal to f. The diameters of the lenses are large, so that they do not contribute to diffraction in this problem. The input wavelength is λ.



(A) First consider the above system as an optical imaging system. Assuming no losses, if the radiant Exitance at the object plane is given by $E(x,y)$ what is the irradiance $M(x,y)$ at the plane **B**.

(B) If we now consider the system as a coherent system in which the object plane is coherently illuminated by a monchromatic plane wave and that the object plane has a field transmission function given by $t_0(x,y)$ what is the electric field at the plane **A**.

(C) Given the electric field at plane A, what is the field at the plane **B**. Discuss weither or not these imaging description in part (A) is consistent with the combine results of parts (B) & (C).

(D) We now place a monochromatic point source on the optical axis in the object plane and place the mask shown above (on the left hand side) in plane **A**. Find the irradiance across the mask in plane A and the irradiance in the plane **B**. Be sure to draw pictures or graphs and discuss the results.

(E) If the point is translated transversely in the image plane explain how the observed irradiance patterns in plane **A** & **B** will change. If you state that no changes are observed in an irradiance pattern explain what is going on.

(3) Modified Young's Double Slit Experiment: Consider a Young's double slit experiment, except that the slits are not the same width. You may assume that the slits are infinitely long and that they are illuminated by a uniform monochromatic plane wave. The width of first slit is ***a*** the width of the second slit is ***b***. The center to center separation of the slits is ***d***. You are to determine the far field diffraction pattern by considering the following:

(A) The pattern from the first slit alone (the second slit is blocked).

(B) The pattern from the second slit alone (the first slit is blocked).

(C) The pattern when both slits open.

For part (C) discuss how the pattern changes as the width of one slit changes. Discuss what happens if the one of the adjustable slits go to zero or becomes very large. To verify your understanding of this problem, please sketch and label graphs of the far field irradiance patterns.

(4) Below is the y-ybar data for an optical system that consist of two thin lenses in air and an aperture stop in between them. The system has an optical invariant Ж=1.

(A) Carefully draw the y-ybar diagram.

(B) Add more points to the y-ybar diagram and label them in accordance to the following key:

AS--aperture stop
E--entrance pupil
E'--exit pupil
P--front principal plane
P'--rear principal plane
F--front focal plane of the system
F'--rear focal plane of the system

Surface	y_j	$\bar{y}_j$
Object	0	-4
L1	3	-1
AS		
L2	1	1
Image	0	1

(C) Find the diameter of the aperture stop

(D) Find the distances between the Object & L1, L1& AS, AS & L2, and L2 & Image

(E) Find the focal length of the total system

(F) Determine the focal length of L1 & L2

(G) Find the minimum diameters of L1 & L2 so that there is no vignetting.