PHYSICS COMPREHENSIVE EXAM 1996
OPTICS SECTION

1. Two half wave plates (linear retarders) are attached to the hour and minute hand, of a clock so that the first half wave plate rotates once per hour and the second rotates once per twelve hours. The fast axes are aligned along the minute and hour hand. A beam of vertically polarized light (E vector in the 6-12:00 o'clock plane) transmits first through the hour hand retarder, then through the minute hand retarder.

   a. Starting from 12:00 o'clock, estimate the first time the light is horizontally polarized (along the 3 - 9:00 o'clock axis).

   b. Describe every time that the light is horizontally polarized.

   c. Two half wave linear retarders with axes $45°$ apart act as a half wave circular retarder. Describe the transformations which this device performs on linear, elliptical, and circularly polarized light.

2. You are given a $100 mm$ and a $-200 mm$ focal length lens.

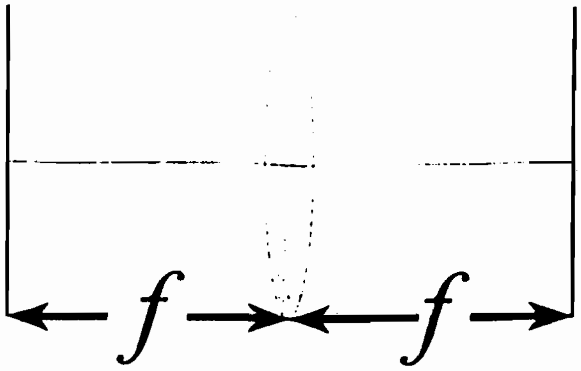
   a. As the separation between the lenses is varied, what is the maximum possible power in diopters?

   b. What is the maximum power? What is the minimum power?

   c. How do the principal planes behave as the lenses are separated? Supply figures.

   d. Consider a source and screen separated by $450 mm$. Arrange the lenses so that an image of magnification -2 is formed.

3. Consider the optical system shown below. The source plane is located at the front focal point and the image plane is located at the rear focal point of a well-corrected optical system with an NA=0.7071. The source plane consists of three evenly space point apertures along the y-axis that are coherently illuminated by a monochromatic plane wave.

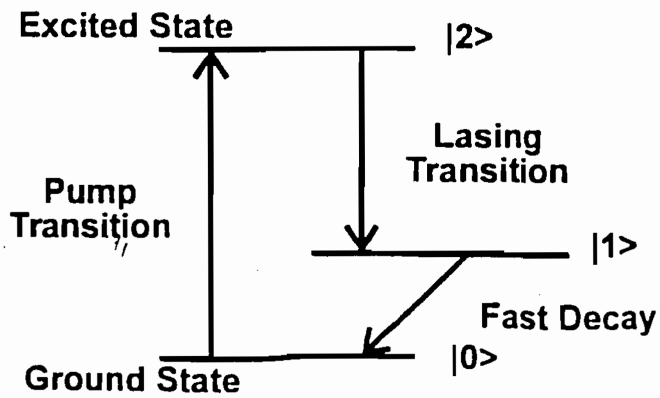


a. Describe the irradiance distribution in the focal plane. Tell how it varies with wavelength, the spacing of the points, focal length of system, etc. Sketch the irradiance distribution in the x&y-directions.

b. How does the irradiance change if a plate with a 1/4 wave phase delay is placed in front of the central point aperture of the source? Sketch the new irradiance distribution.

c. How does the irradiance change if a ½ wave phase delay is introduced in front of the central point aperture of the source?

4. (Note: Stefan-Boltzmann Constant $\sigma_B = 5.6697 \times 10^{-12}$ watts/cm^2°K^4.) Lasers in Space. There are recient reports on the observation of Stimulated Emisson or Laseing observed in clouds near stars. To model this, consider the three level system shown below.



The star light pumps the atoms into a metastable state excited state, |2>. The atom emits a photon when it decays to the intermediate state |1>. This transition is either spontaneous or may be stimulated if other photons at this frequency are present. The upper-state, |2>, lifetime is 10^{-8} sec and the intermediate level, |1>, lifetime is 10^{-9}

a. The star's surface temperature is 6000°K (similar to the sun). The cloud of atoms of interest is 6 star diameters (1 diameter = 10^9 meters) away. It is about 0.1 diameter thick. Find the star flux irradiance on the atoms in these cloud. Find the energy density of the stars flux at the cloud.

b. Only 0.1% of this energy is within the 1nm bandwidth of the $|0>$ to $|2>$ pump transition. The Einstein B coefficient for the pump transition is $B_{20}=3\text{x}10^{10}$ [nm cm^3/Joule secs]. Ignoring any stimulated emission between the $|2>$ & $|1>$ levels and assuming a closed 3 level system, write out the rate equations for the population density in the three levels. Find the percentage of atoms in each of the levels.

c. The atoms in the clouds are randomly distributed with a density N [atoms/cm^2]. The cross-section for the $|2>$ to $|1>$ transition is $\sigma=10\mu\text{m}^2$. On the average a photon emitted from an atom will encounter another atom after traveling an average distance of $L=1/\sigma N$. (Hey be thank we didn't make you derive that one.) Find the density N of the atoms in the clouds such that on the average a photon starting off at the inside of the cloud will created 10 additional photons by stimulated emission.