End Semester Examination, July 2023

Course Code: PH2000
Category: Elective
Duration: 3 hours

Course Title: Engineering Optics
Date of Examination: 07-07-2023
Max. Marks: 50

Instructions to students:

- Please read the questions carefully and answer all the questions.

$k_B = 1.38 \times 10^{-23}$

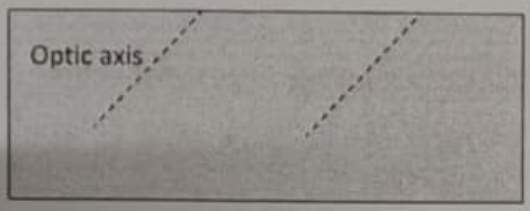
1. (a) Explain Brewster's law of polarization with diagram indicating states of polarization of light.

(b) For an air-liquid interface, if the Brewster's angle is 53°, what is the refractive index of the liquid?

(c) Consider a monochromatic beam of wavelength 6000 Å incident on a Fabry–Perot etalon with $n_2 = 1$, h = 1 cm, and F = 200. Concentric rings are observed on the focal plane of a lens of focal length 20 cm. Calculate the reflectivity of each mirror. Justify your answer. (2+1+3)

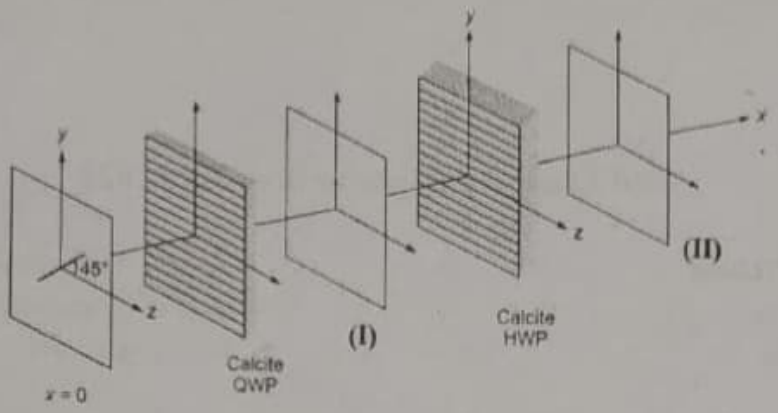
2. (a) What are positive and negative crystals? Give one example of each of them.

(b) How will the different wavefronts of light travel when incident normally on the positive crystal shown below? The optic axis is shown as the dashed line. (2+3)

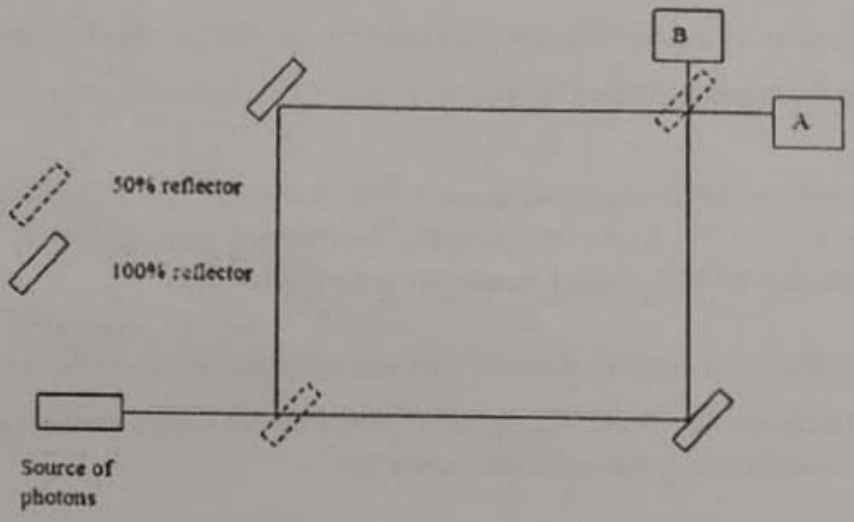


3. (a) A left circularly polarized beam ($\lambda_0 = 5893$ Å) is incident normally on a calcite crystal (with its optic axis cut parallel to the surface) of thickness 0.005141 mm. What will be the state of polarization of the emergent beam? $n_0 = 1.65836$ and $n_e = 1.48641$.

(b) A linearly polarized light is incident at 45° on a calcite quarter wave plate (QWP), as shown below (on page 2). Determine the state of polarization of the emergent beam (I) which then falls on a calcite half wave plate (HWP). Determine the state of polarization of the final beam (II) emerging from the HWP. The direction of the optic axis of QWP and HWP are shown by the horizontal lines. (3+3)



4. For the Mach-Zehnder interferometer shown below, calculate the total phases for each of the paths of light and show that detectors A and B must record opposite kind of interference as output. Assume that the 1st beam splitter is coated on the front side while the 2nd one is coated on the back side. (5)



5. (a) Discuss the working principle and structure of an optical fiber.

(b) Calculate the ratio of population densities of upper and lower laser levels when the wavelength separation between them is 1 μm at 300K. (3+2)

6. (a) Light coming from an optical fiber produces a spot of diameter 4 cm on a screen kept at a distance 50 cm away from the output end of the fiber. What is the numerical aperture of the optical fiber?

(b) If the power of a 10mW laser beam decreases to 2 mW after traversing through 60 km of an optical fiber, what is the attenuation (loss) of the fiber per km? (2+2)

7. (a) A 40 km fiber link has a loss of 0.6 dB per km. If each of the three connectors in its path has a loss of 1.6 dB, calculate the total loss.

(b) Another 40 km fiber link has a loss of 0.3 dB per km. If each of the three connectors in its path has a loss of 1.2 dB, calculate the total loss.

(c) Provided with the above information for these fiber links, you are now asked to place repeaters for both the cases so that the fiber links can work effectively. Suppose the distance between successive repeaters you are going to place for case (a) is d_1 and for (b) it is d_2. Which one is true and why? (i) $d_1 = d_2$ (ii) $d_1 > d_2$ and (iii) $d_1 < d_2$. (2+2+2)

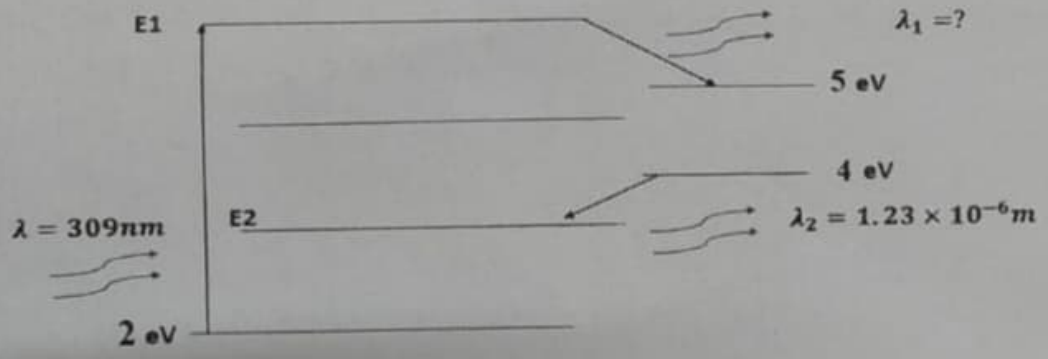
8. (a) What are the main components of a laser? Describe briefly.

(b) A 20-mW laser is emitting at a mean wavelength of 500 nm. Determine the rate of occurrence of stimulated emission. (3+2)

9. (a) Briefly explain the working principle of any three-level laser with energy level diagrams.

(b) In a Nd:YAG laser rod, Nd^{3+} ion has a density of $1.5 \times 10^{26}/m^3$. If the ions are pumped to an upper level from where they cascade downwards emitting a radiation of 1050 nm, calculate the energy radiated per cubic meter of the rod.

(c) Determine the unknown energy levels E_1, E_2 and the value of λ_1 from the energy diagram of a four-level laser given below. (3+2+3)



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