Course Name: Nano-Technology
Course Code: MPE471
Summer Semester Exam.
BME Program - Level 400
Open-notes Exam.
Exam Date: 27-8- 2019
Allowed Time: 2 Hours

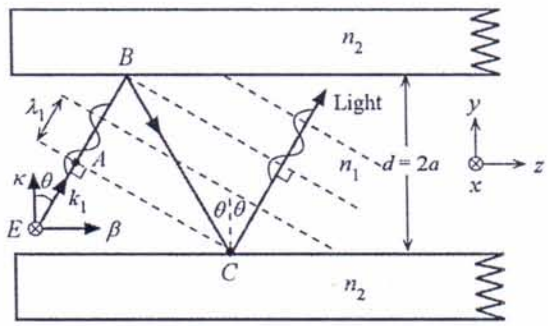
Answer the following question:

Q.1) Write a short note on each of the following: **[20 Marks]**

a. Optical Anisotropy
b. Birefringent Optical Devices
c. Liquid Crystal Displays
d. Electro-Optic Effects
e. Acousto-Optic Modulator

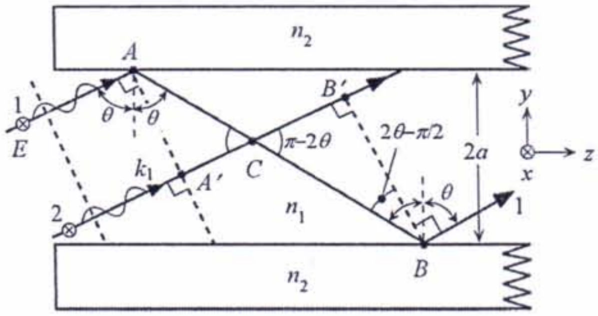
Attempt only three questions of the following:

Q.2) A light ray travelling in the guide must interfere constructively with itself to propagate successfully. Otherwise destructive interference will destroy the wave. E is parallel to x. (λ_1 and k_1 are the wavelength and the propagation constant inside the core medium n_1 i.e. $\lambda_1 = \lambda/n_1$)



a) Prove that only certain angles are allowed. Each allowed angle represents a mode of propagation; i.e. prove the following equation (waveguide condition):

$$\left[\frac{2\pi n_1(2a)}{\lambda}\right]\cos\theta_m - \varphi_m = m\pi$$



b) Consider the two parallel rays 1 and 2 in Figure 2. Show that when they meet at C at a distance y above the guide center, the phase difference is
$\emptyset_m = k_1 2(a - y)\cos\theta_m - \varphi_m$ **[10 Marks]**

Q.3) A light wave with a free space wavelength of 890 nm (free space wavelength) that is propagating in GaAs becomes incident on AlGaAs. The refractive index of GaAs is 3.60, that of AlGaAs is 3.30.

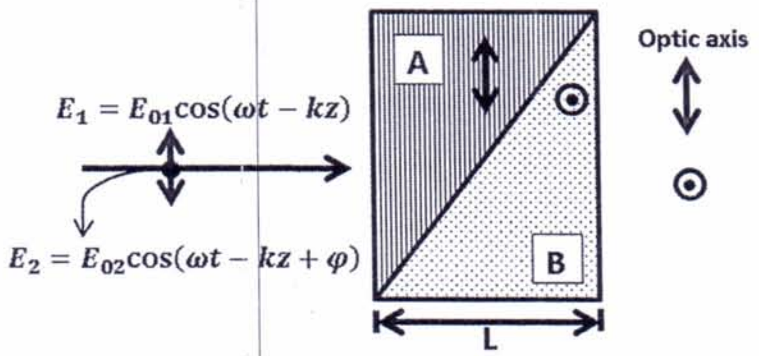
(a) Consider normal incidence. What are the reflection and transmission coefficients? (From GaAs into AlGaAs)

(b) What is the Brewster angle (the polarization angle θ_p) and the critical angle (θ_c) for total internal reflection for the wave in (a); the wave that is traveling in GaAs and incident on the GaAs/AlGaAs interface.

(c) What is the reflection coefficient and the phase change in the reflected wave when the angle of incidence $\theta_i = 79°$?

(d) What is the penetration depth of the evanescent wave into medium 2 when $\theta_i = 79°$ and when $\theta_i = 89°$? What is your conclusion? **[10 Marks]**

Q.4) Consider a Rutile (TiO2) Wollaston prism (with ne=2.903 and no=2.616) shown:



a. Draw clearly and identify the directions of orthogonally polarized waves travelling through the prisms (A and B)

b. Redraw (a) for a Tourmaline Wollaston Prism (with ne=1.638 and no=1.669)

c. Redraw (a) if the Prism A and B exchange their Places

d. If we replace Prism A by a prism identical to B (i.e has the same optical axis), Draw clearly and identify the directions of orthogonally Polarized waves travelling through the prisms.

e. If we replace Prism B by a prism identical to A (i.e. has the same optical axis), Calculate length L such that for a ray with wavelength $\lambda = 633\ nm$ the phase shift between the two orthogonally polarized waves travelling through the prism equal to $\frac{\pi}{4}$. Describe the polarization of the outgoing ray after passing through the two prisms if $E_{01} = 2E_{02}$ **[10 Marks]**

Q.5) Suppose that we write the E_x and E_y components of light wave generally as:

$$E_x = E_{x0}\cos(\omega t - kz)$$

$$E_y = E_{y0}\cos(\omega t - kz + \varphi)$$

a) Show that at any instant E_x and E_y satisfy the ellipse equation on the E_x vs E_y coordinate system:

$$\left(\frac{E_x}{E_{x0}}\right)^2 + \left(\frac{E_y}{E_{y0}}\right)^2 - 2\left(\frac{E_x}{E_{x0}}\right)\left(\frac{E_y}{E_{y0}}\right)\cos(\varphi) = \sin^2(\varphi)$$

b) Sketch schematically what this ellipse looks like assuming $E_{x0} = 2E_{y0}$. When would this ellipse form:

i) Ellipse with its major axis on the x-axis

ii) A Linear polarized light at 45^o

iii) Right circular polarized light

iv) Left circular polarized Light **[10 Marks]**
