Course Name: NanoTechnology
(Nanophotonics)
Course Code: MPE471
Midterm Exam.
BME Program
Level 400
Exam Date: 03-04- 2019
Allowed Time: 60 Minutes

Attempt all questions. Assume any missed data. Full mark is 30.

Q.1 [5 Marks] Lateral displacement of light occurs when a beam of light passes obliquely through a plate of transparent material, such as a glass plate. When a light beam is incident on a plate of transparent material of refractive index **n**, it emerges from the other side traveling parallel to the incident light but displaced from it by a distance **d**, called lateral displacement. Find a mathematical expression for the displacement **d** in terms of the incidence angle θ_i, the plate thickness **L**, and **n** **only**.

Q.2 [9 Marks] Imagine an electromagnetic plane wave in vacuum has E-filed (in SI units) given by:

$E_x = 10^2 \sin \quad (3\pi \times 10^6 z - 9\pi \times 10^{14} t), E_y = 0,\ E_z = 0.$

(a) If the wave function has the basic form $E_x(z,t) = E_0 \cos[k(z - vt)]$, **Determine**:

1. The speed.
2. Wavelength.
3. Period.
4. Initial phase.
5. Polarization of the wave.

(b) Write an expression for the magnetic field B associated with the wave i.e. (the three components $B_x, B_y and\ B_z$).

(c) Consider a light of free-space wavelength 1300 nm traveling in pure silica medium ($n = 1.447, N_g = 1.462$). Calculate the phase velocity and group velocity of light in this medium. Is the group velocity ever greater than the phase velocity?

Q.3 [7 Marks] Ahmed and Bahaa aim to attend a football match for Liverpool team. Before they go to the match, they went to supermarket to buy two laser pens A "for Ahmed" and B "for Bahaa". The two laser pens are different and have the following relation $\lambda^A = \frac{4}{9} \times \lambda^B$ and $beam\ waist\ of\ A = \frac{2}{3} \times beam\ waist\ of\ B$. If Ahmed and Bahaa set in the stadium next to each other "at same line".

1) At 1.8 m from their seats, it is observed that the intensity of Ahmed laser pen was reduced to half. What is required distance such that the intensity of Ahmed laser pen was reduced to half as well?
   a) 0.8 m b) 2.4 m c) 1.8 m d) 1 m

2) If the divergence angle of Ahmed's laser pen is equal to 0.018^o . Then the divergence angle of Bahaa's laser pen is equal to
   a) 0.008^o b) 0.024^o c) 0.012^o d) 0.018^o

3) Mohamed Salah stands at football playground at distance of 25 m away from Ahmed and Bahaa seats. Ahmed and Bahaa focus their laser on Mo Salah. It is observed
   a) Spot size of Ahmed beam > Spot size of Bahaa beam
   b) Spot size of Ahmed beam < Spot size of Bahaa beam
   c) Spot size of Ahmed beam = Spot size of Bahaa beam
   d) Spot size of Ahmed beam = 2 x Spot size of Bahaa beam

Q.4 [8 Marks] Light is travelling from a glass medium of refractive index $n_1 = 1.45$ to a less dense glass medium of refractive index $n_2 = 1.43$ with incident angle θ_i

1) If $\theta_i = 20^o$, the reflection coefficient for $E_\perp$, $(\Gamma_\perp)$ is equal to
   a) Zero b) 1 c) $0.33 + j0.44$ d) 7.88×10^{-3}

2) If $\theta_i = 50^o$, the phase change between $E_{i,//}$ and $E_{r,//}$, $(\varphi_{//})$ is equal to
   a) Zero b) 33.2^o c) -67.2^o d) -180^o

3) If the reflection coefficient for parallel component $(\Gamma_{//})$ is equal to zero, then the incident angle is
   a) 80.473^o b) zero c) 44.602^o d) 32.601^o

4) If $\theta_i = 85^o$, the reflection coefficient for normal component , $(\Gamma_\perp)$ is equal to
   a) $1.02 + j0.04$ b) $0.02 + j1.23$ c) 2 d) $-(0.445 + j0.895)$

My best wishes to all of you!

Bahaa Younis

Dr Ahmed Heikal

$$r_{\perp} = \frac{E_{r0,\perp}}{E_{i0,\perp}} = \frac{\cos\theta_i - \left[n^2 - \sin^2\theta_i\right]^{1/2}}{\cos\theta_i + \left[n^2 - \sin^2\theta_i\right]^{1/2}}$$

$$r_{//} = \frac{E_{r0,//}}{E_{i0,//}} = \frac{\left[n^2 - \sin^2\theta_i\right]^{1/2} - n^2\cos\theta_i}{\left[n^2 - \sin^2\theta_i\right]^{1/2} + n^2\cos\theta_i}$$

$$t_{\perp} = \frac{E_{t0,\perp}}{E_{i0,\perp}} = \frac{2\cos\theta_i}{\cos\theta_i + \left[n^2 - \sin^2\theta_i\right]^{1/2}}$$

$$t_{//} = \frac{E_{t0,//}}{E_{i0,//}} = \frac{2n\cos\theta_i}{n^2\cos\theta_i + \left[n^2 - \sin^2\theta_i\right]^{1/2}}$$

$$T_{\perp} = \frac{n_2\cos\theta_t\left|E_{to,\perp}\right|^2}{n_1\cos\theta_i\left|E_{io,\perp}\right|^2} = \left(\frac{n_2\cos\theta_t}{n_1\cos\theta_i}\right)\left|t_{\perp}\right|^2$$

$$T_{//} = \frac{n_2\cos\theta_t\left|E_{to,//}\right|^2}{n_1\cos\theta_i\left|E_{io,//}\right|^2} = \left(\frac{n_2\cos\theta_t}{n_1\cos\theta_i}\right)\left|t_{//}\right|^2$$

$$R_{\perp} = \frac{\left|E_{ro,\perp}\right|^2}{\left|E_{io,\perp}\right|^2} = \left|r_{\perp}\right|^2 \qquad R_{//} = \frac{\left|E_{ro,//}\right|^2}{\left|E_{io,//}\right|^2} = \left|r_{//}\right|^2$$

$\tan\left(\frac{1}{2}\phi_{\perp}\right) = \frac{\left[\sin^2\theta_i - n^2\right]^{1/2}}{\cos\theta_i}$	$\tan\left(\frac{1}{2}\phi_{//} + \frac{1}{2}\pi\right) = \frac{\left[\sin^2\theta_i - n^2\right]^{1/2}}{n^2\cos\theta_i}$
$\alpha_2 = \frac{2\pi n_2}{\lambda}\left[\left(\frac{n_1}{n_2}\right)^2\sin^2\theta_i - 1\right]^{1/2}$	

$$z_o = \frac{\pi w_o^2}{\lambda} \qquad \theta = \lambda/(\pi w_o)$$

$$2w = 2w_o\left[1 + \left(\frac{z}{z_o}\right)^2\right]^{1/2}$$

$$\frac{d}{L} = \sin\theta_i\left[1 - \frac{\cos\theta_i}{\sqrt{(n/n_o)^2 - \sin^2\theta_i}}\right]$$