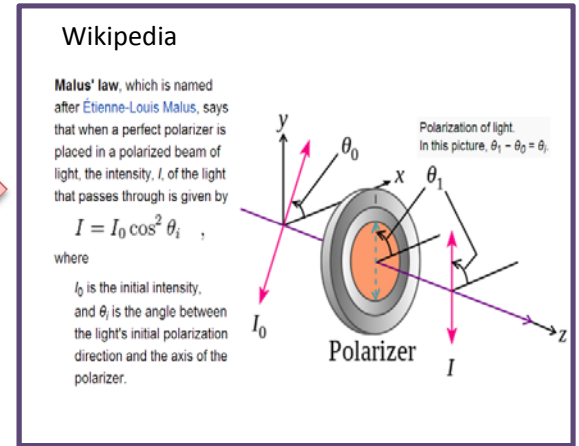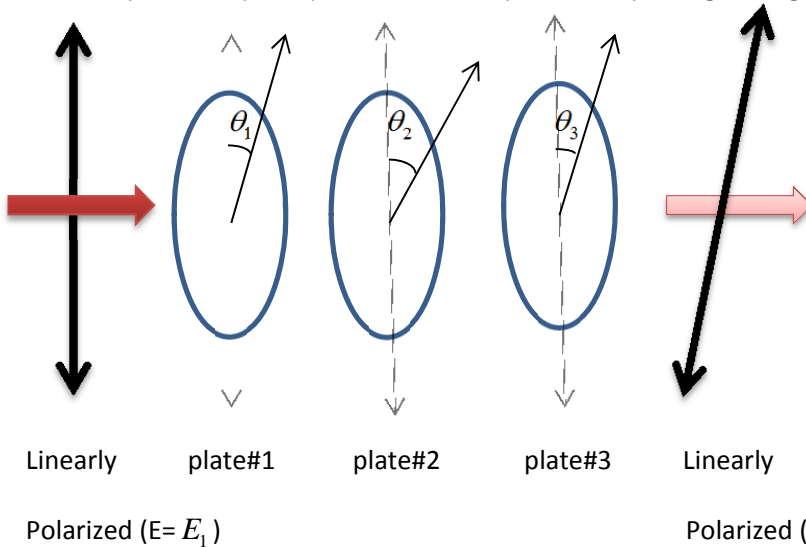Assignment#2, Fundamentals in BioPhotonics 2021

1) (%10)

The angles between the polarizing plates and linearly polarized input beam are given in the figure below. Find the probability of a photon (in the input beam) passing through all the polarizers.

Wikipedia

Malus' law, which is named after Étienne-Louis Malus, says that when a perfect polarizer is placed in a polarized beam of light, the intensity, I, of the light that passes through is given by

$$I = I_0 \cos^2 \theta_i \quad,$$

where

I_0 is the initial intensity, and θ_i is the angle between the light's initial polarization direction and the axis of the polarizer.

Polarization of light. In this picture, $\theta_1 - \theta_0 = \theta_i$.

Linearly   plate#1   plate#2   plate#3   Linearly

Polarized (E= E_1)   Polarized (E= E_2)

2) (%15)

Find the polarization states (circular, linear, elliptical) and the magnetic fields of the EM waves described by the following equations.

A) $E_y = 2E\sin(kx + wt)$ and $E_z = 3E\cos(kx + wt + \frac{\pi}{2})$

B) $E_y = 2E\sin(kx + wt)$ and $E_z = 3E\sin(kx + wt)$

C) $E_y = -E\sin(kx + wt)$ and $E_z = E\cos(kx + wt)$

3) (%20)

Wave plates are birefringent materials that change the polarization state of a beam depending on their thickness (d). In these devices, the ordinary axis generates a phase of $e^{\frac{2\pi}{\lambda}dn_x}$ for E_x field while the extraordinary axis generates $e^{\frac{2\pi}{\lambda}dn_y}$ phase difference for E_y field (n_x, n_x are the refractive indexes). The phase difference for quarter wave plates (QWP) and for half wave plates (HWP) are $\frac{\pi}{2}$ and π respectively.

A) Assume a $\dfrac{\pi}{4}$ degree polarized input beam and find the jones vector representation of the output beam if it is passing through a QWP/HWP.

B) Find the polarization state of a α -degree linearly polarized input beam that is passing through a HWP (use jones vector representation).

C) Find the polarization state of a α -degree linearly polarized input beam that is passing through a QWP/HWP (use jones vector representation).

4) (%10)

An optical isolator is a device that allows the propagation of a beam in one direction. In the figure below, design a setup such that the reflected beam doesn't back propagate to the laser. In this case your setup will operate as optical isolator. You can use HWPs and QWPs as much as you want.

Mirror

5) (%5)

The main idea in polarized sunglasses is to filter reflected photons. If photons gain a polarization that is parallel to the reflecting surface find the polarization directions of the ideal sunglasses for surfing. (Hint: the pair below is not a good choice)

6) (%40)

Jones matrices are the representation of optical elements that are used when we define the waves as jones vector. If V_i is the input wave for the optic element and V_o is the output wave then M is the jones matrix of the optic element if it is satisfying $M.V_i = V_o$.

A) Find jones matrix of a rotator that rotates the polarization state by θ .

B) Use the results you found in Problem#3 and find the Jones matrix representation of a HWP

C) Verify your answer in problem#1 use jones matrix representation

D) A linearly polarized (in horizontal direction) wave is passing through two linear polarizers. The first is oriented with its transmission axis 45 degrees and the other one is vertical. Show that the output is linearly polarized and has been rotated 90 degrees with respect to the input.

E) Verify that a circularly polarizer (whose jones matrix is $\begin{bmatrix} 1 & i \\ -i & 1 \end{bmatrix}$) completely transparent to one type of circularly polarized right (right or left?) and opaque to the opposite circular polarization.