Optics

Polarizers

Malus law for polarizers

$$I_{after} = I_{before} \times (\cos\theta)^2$$

where θ is the angle between the polarization of the incident light and the axis of the polarizer.

Problem 1.- Calculate the irradiance left after natural light of intensity I_o goes through the cascade of polarizers described in the following cases:

a) Two HN44 polarizers that make 45º with respect to each other.

b) One HN44 polarizer.

c) Two HN44 polarizers that are aligned with each other.

Solution:

a) Two HN44 polarizers that make 45º with respect to each other.
$0.44 \times 0.88 \times \cos^2 45^\circ I_o =$ **$0.1936I_o$**

b) One HN44 polarizer.
$0.44 I_o =$ **$0.44I_o$**

c) Two HN44 polarizers that are aligned with each other.
$0.44 \times 0.88 =$ **$0.3872I_o$**

Problem 2.- Unpolarized light of intensity I_0 is incident on a series of three polarizing filters. The axis of the second filter is oriented at 45° to that of the first filter, while the axis of the third filter is oriented at 90° to that of the first filter. What is the intensity of the light transmitted through the third filter?

(A) 0
(B) $I_0/8$
(C) $I_0/4$
(D) $I_0/2$
(E) I_0

Solution: The first polarizer reduces the intensity by half, the second by $\cos^2 45^\circ$ and the third also by $\cos^2 45^\circ$, so the answer is **(B) $I_0/8$**

Problem 3.- Unpolarized light is incident on three ideal linear polarizers whose transmission axes make an angle of 120° with each other. The transmitted light intensity through all three polarizers is what percentage of the incident intensity?

(A) 28.1%
(B) 25%
(C) 12.5%
(D) 6.25%
(E) 3.12%

Solution: The first polarizer produces a drop in intensity of ½
The next two polarizers will introduce a factor of $\cos^2 120^\circ = 1/4$ each one, so the final intensity will be

$$\frac{1}{2}\times\frac{1}{4}\times\frac{1}{4}=\frac{1}{32}=3.125\%$$

Answer: **E**

Problem 4.- Unpolarized light is incident on two ideal polarizers in series that are rotated 90 degrees with respect to each other, so no light goes through the second polarizer.
Then you insert a third polarizer in between the other two and rotate it until you get the maximum possible output of the three polarizers.
What fraction of the incident intensity is that maximum?

Solution: To get the maximum intensity we can set the second polarizer at 45 degrees with respect to the other two then the first will produce ½ of intensity and the other two also ½ due to Malus law giving a final intensity of **12.5%** of the incident value.

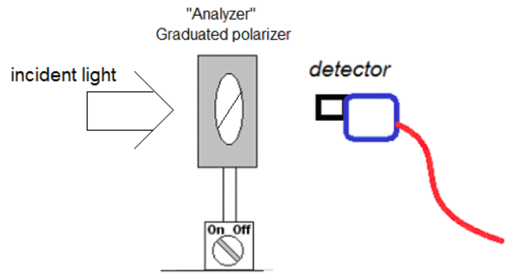
Problem 5.- Calculate the irradiance left in the following cases:

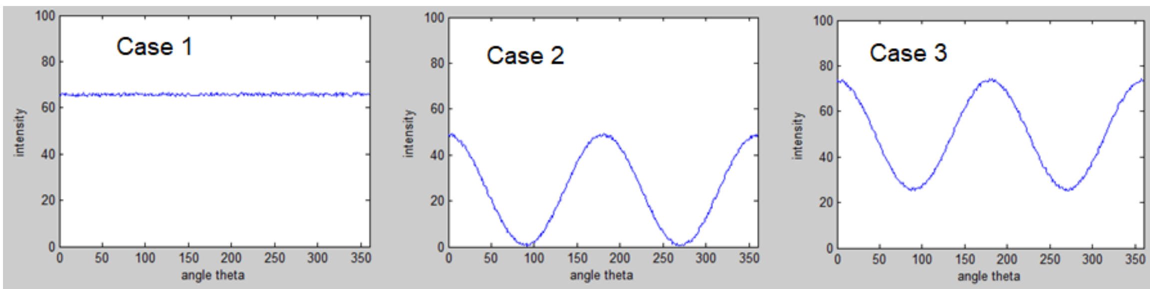
a) Source of unpolarized light of intensity I_o followed by an HN50 polarizer.
b) Source of unpolarized light of intensity I_o followed by an HN32 polarizer.
c) Source of unpolarized light of intensity I_o followed by two HN44 polarizers that make 30º with respect to each other.
d) Source of unpolarized light of intensity I_o followed by two HN44 polarizers that make 90º with respect to each other.
e) Source of unpolarized light of intensity I_o followed by three HN44 polarizers that make 45º with respect to each other.

Solutions: The irradiance left is:

a) $0.5I_o$
b) $0.32I_o$
c) $0.29I_o$
d) zero
e) $0.085I_o$

Problem 6.- The following graphs show intensity as a function of angle measured with a linear polarizer (an "analyzer"). Based on the intensity observed, identify what kind of polarization or combination of polarizations you have in each case. Explain briefly your rationale.





Solution:

Case 1.- This could be done by unpolarized light or by circularly polarized or a combination of both. The reason is that when this kind of light goes through a polarizer half of its intensity is lost regardless of the angle of orientation giving a constant intensity.

Case 2.- This could be done by linearly polarized light, which follows Malus law of a cosine squared.

Case 3.- This could be done by a combination of linearly polarized light, which contributes an oscillating intensity that follows Malus law and circularly polarized light, which contributes a constant intensity.

There are other possibilities, for example a combination of linearly polarized light and unpolarized light or simply elliptically polarized light.