**Homework 1- Wave Optics. Solutions**

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Deadline to give me back the homework: 18th May 2021

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**Ex. 1: Thin film interference for any incidence angle**

As shown on the figure, we wish to describe the thin film interference between two rays at C. We consider any incidence angle (same for both rays ). The phase of both waves is the same at A and D. The optical path difference between both waves at C, ***if we don’t consider the possible extra-path difference due to the reflections***, is: where , are respectively the optical path travelled from A to B (ray 1), from B to C (ray 1) and from D to C (ray 2). The surface which separate media of refractive index and is almost horizontal, which means that we can do the approximation .

(1) Describe in terms of where the angle of refraction and the distance d are shown on the figure.

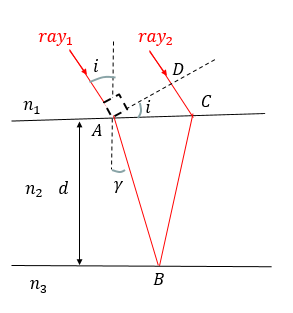
(2) Describe in terms of the distance and the incidence angle . And describe the distance in terms of the distance and the angle of refraction . You obtain an expression of in respect with the angle of incidence , the angle of refraction , and .

(3) Using the Descartes’s law of refraction describe in terms of .

(4) Demonstrate that

(5) Considering the refractive indices are such as there is half-wave loss at B and no half-wave loss at C, what is the difference of optical path between both waves at C. What can you say about refractive indices and ?

**Warning:** any incidence angle is considered**, it is not possible** to do the approximation .



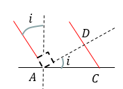
**Solution**

(1)

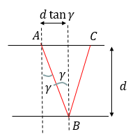
Because AB,

(2)

which is obtained using the triangle ADC as follows:



which is obtained using the triangle ABS as follows:



We obtain:

The optical path from D to C is:

(3)

Using the Snell-Descartes law for the refraction, we have:

We obtain:

(4) The optical path difference between both rays at C, if we don’t consider possible extra-path due to reflections is:

**Comment:** For an almost normal incidence, then

There is no contradiction with the previous result obtained for any incidence, because at almost normal incidence, , thus .

5) Now we consider the possible half-wave loss.

At B, there is half-wave loss due to the reflection, i.e. an extra- path of ( is the wavelegth in the medium of refractive index ) must be added, and at C there is no half-wave loss, no extra- path must be added at C. Considering the extra-path difference between the waves due to the reflection, the path difference between them is, at C:

where is the path difference between the waves (without considering the extrapath due to the reflection).The optical path difference between the waves is, at C:

Where is the wavelength in vacuum of the waves (same for both waves).

There is an half-wave loss at B, thus here .

There is no half-wave loss at C, thus here

**Comment:**

The result is wrong (exepted if you say that is the wavelength in vacuum but please to use for the wavelength in vacuum which permits to avoid confusion). If the medium of propagation is air , then but this was not noticed in the exercise.

**Ex. 2. A Young’s holes experiment where the phase is not the same at and**

We consider a Young’s holes experiment as described on the figure. The pinholes are seen as source points. We want to describe the intensity at any point P on the x-axis described on the figure (i.e. the coordinate of P are: ). The point source is located on the z-axis. Its coordinates are . The point source is at distance from . Its coordinates are . The phase of the waves at point sources and respectively named and are not the same because and are not at the same distance from the point source . The light propagates through air of refractive index .

1) Describe rigourously (i.e. without any approximation) the optical path from to in terms of , and .

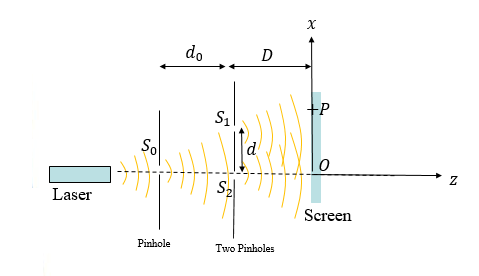
2) Describe rigourously , the optical path from to P in terms of and .

3) To evaluate the phase differences between both waves at P, we will first describe the difference of optical path . Use the approximation and consider the screen is far from the pinholes relatively to the distance between the pinholes () to describe an approximated value of the difference of optical path in terms of , if the point P is quite close to the z-axis to consider .

4) The last step to describe the phase difference between waves at P is to estimate the phase difference between the waves at and .Describe rigousously in terms of the wavelength in vacuum of the incident light, n, and (the distance is descibed on the figure). Conclude about the phase difference between both waves at P you have described in this exercise and the phase difference between both waves when and are at the same distance from as seen during the lecture (you don’t have to desmonstrate it, you can use the result seen on the lecture ).

**Hints:** if <<1, then

Considering two positives numbers and , if , then .



**Solution.**

1)

Where is the distance from to .

2) is the distance from to .

The optical path from to is :

3)

Using the approximation , we have:

Using the approximation ,

The difficulty of the exercise was to understood how to use the approximation if .

, then

And using , we have , i.e.

The approximated evaluation of is more easy to describe:

We obtain the approximated value of the difference of optical path

4) The difference of phases between the waves at point sources and is:

Take care that here , then .

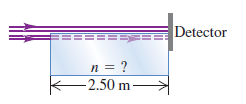
As previouly, we could describe an approximated value of this phase difference, but no conditions about which permit to do approximations was given on the exercise.

The phase difference between both waves at P are described (approximately) by the same equation in terms of when the two sources points and are at the same distance from and when they are not at the same distance from , exepted a phase shift , which depends on , must be considered in that case.

**Ex. 3.**

A laser beam shines along the surface of a block of transparent material (see the figure). Half of the beam goes straight to a detector, while the other half travels through the block and then hits the detector. The time delay between the arrival of the two light beams at the detector is 6.25 ns. (1) What is the time for the light to travel the distance of through air (unit: s)? (2) What is time for the light to travel the distance of 2.50 m through the block of transparent material (unit: s). (3) Deduce the velocity of propagation of light (unit: ) in the material and the refractive index of the material.

For refractive index in air, please to take . For the light speed in vacuum, use the value .



Solution :

(1)

The time for the beam to reach the detector, in air, is

(2)

The time for the beam to reach the detector, in the material, is:

(3)

We have

where is the velocity of the propagation of the light in the materical:

The refractive index must be greater than 1, because is the maximum speed of light (the speed of light in a medium of refractive index is ). If you find a refractive index , you have certainly done a mistake somewhere.