Wed Jan 31.

Announcements

• Help sessions:
  • W 9 - 10 pm in NSC 118
  • MasteringPhysics
  • Hwk #1 due Friday

Ch. 22: Wave Optics

Young's Experiment
(circa 1800)

To demonstrate the interference properties of light waves.

The screen is used to produce a coherent, in phase light source for the slits in the second screen.

Viewing Screen

Ch. 22: Wave Optics

Now we've created an experiment for light that is completely analogous to the sound in the field around our outdoor stage.

monochromatic light source

crests

troughs

bright

dark

Ch. 22: Wave Optics

So what do we actually see projected on the screen???

The bright lines dim as we move away from the center.

Alternating bright and dark regions called fringes!

Ch. 22: Wave Optics

The bright fringes appear where the light waves from the two sources arrive in phase. They represent constructive interference.

central maximum

double slit

The crests arrive at the same time.
The dark fringes appear where the light waves from the two sources arrive 180° out of phase. They represent *destructive interference*.

If we keep moving down the screen, we’ll find the first-order maximum. At this point, the waves are effectively in phase again.

Constructive interference at the bright fringes

A little geometry allows us to locate the position of the maxima and minima more precisely:

For small $\theta$:

So, \( \delta \equiv \frac{yd}{L} \)

The maxima will occur when $\delta$ is an integer ($m$) multiple of the wavelength of the light:

\[ \delta = d \sin \theta = m\lambda \]

The minima will occur when $\delta$ is an integer number ($m$) plus one half times the wavelength of the incident light:

\[ \delta = d \sin \theta = (m + \frac{1}{2})\lambda \]
A Young's interference experiment is performed with monochromatic light. The separation between the slits is 0.500 mm and the interference pattern on the screen 3.30 m away shows the first maximum 3.40 mm from the center of the pattern. What is the wavelength of the light?

1) 258 nm  
2) 515 nm  
3) 1010 nm  
4) 151 μm  
5) 1.01 mm  
6) impossible to determine

Last time, we saw that the effective amplitude of two interfering waves was

\[2A \cos \left( \frac{\phi}{2} \right)\]

We just need to know what the phase difference, \(\phi\), is. We can compute that from the path difference and the wavelength.

Now, use the small angle approximation we saw last time

\[\delta \equiv \frac{yd}{L}\]

There is another way we can produce two coherent light sources besides using the double slit...

But the interference pattern that is observed on the screen is **EXACTLY THE OPPOSITE** of what we saw in Young’s Experiment!!!!

It turns out that light undergoes a phase shift of exactly 180° (one-half a wavelength) when it bounces off the mirror!
In general, any time light reflects off the boundary of a material with a higher index of refraction than that in which the incident light travels, a phase shift of $180^\circ$ will occur.

Air, $n = 1$

incident

reflected

mirror, $n > 1$

crest
trough

No phase change occurs when light reflects off a boundary leading to a medium with a lower index of refraction.

Air, $n = 1$

Water, $n = 1.33$

Air, $n = 1$

The closer to normal the incident light is on the top surface of the layer of water, the closer the reflected rays from the top and the bottom surface will be.

Air, $n = 1$

Water, $n = 1.33$

Air, $n = 1$

If the reflected rays lie on top of one another (as will be the case if the light is normally incident on the top surface), the reflected rays can interfere with one another!

$\text{Phase shift}$

Air, $n = 1$

Water, $n = 1.33$

Air, $n = 1$

The path length difference is $2t$

So, if the path difference ($2t$) is an integer multiple of the wavelength of the light, we will get destructive interference between the

Be Careful!

Here, the relevant wavelength of the light is its wavelength in the medium!

$\lambda_n = \frac{\lambda}{n}$

For the case of a thin film of index of refraction $n$ surrounded by air, the maxima and minima occur under the following conditions:

$2t = (m + \frac{1}{2})\lambda_n$ (Constructive interference)

$2t = m\lambda_n$ (Destructive interference)
In this case, the blue and yellow rays have suffered a 180° phase change, so the conditions for maxima and minima are exactly the opposite of what appears on the last slide!

Air, \( n = 1 \)

Water, \( n = 1.33 \)

Glass, \( n = 1.5 \)

For rays travelling from low \( n \) toward high \( n \), a 180° phase shift will occur for the reflected ray.

Then, simply calculate the difference in path length based upon the thickness of the film.

When working problems with thin films, you must first evaluate what happens to the reflected ray at each boundary.

For rays travelling from high \( n \) toward low \( n \), no phase shift will occur for the reflected ray.

For cases in which both reflected rays suffer the same fate (either phase shifted or not), path length differences of 1/2 a wavelength lead to destructive interference.

For cases in which one reflected ray suffers a phase shift of half a wavelength, path length differences of 1 full wavelength lead to destructive interference.

A beam of light of wavelength 580 nm passes through two closely spaced glass plates as shown. What is the minimum plate separation \( d > 0 \) for which the transmitted light be maximally bright?

1) 145 nm
2) 290 nm
3) 435 nm
4) 580 nm
5) 725 nm
6) 1160 nm
7) Cannot determine