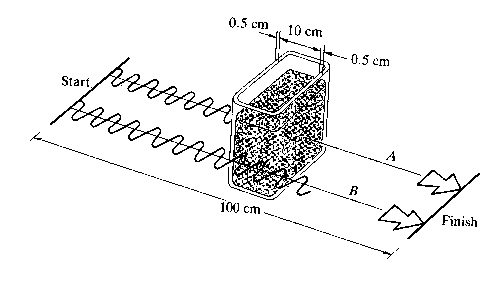
**Homework for General Physics III Set4**

**By Zhao Wen**

1. **(Hecht’s 7.6)Determine the optical path difference for the two waves A and B, both having vacuum wavelengths of 500nm. The glass (n=1.52) tank is filled with water (n=1.33). If the waves start out in-phase and all the above numbers are exact, find their relative** **phase difference at the finishing line.**

Answer:

****

The waves start out in-phase:

Phase difference:

∴They are still in-phase at the finishing line.

1. **(Hecht’s 7.15)Imagine that we strike two tuning forks, one with a frequency of 340 Hz, the other 342 Hz. What will we hear?**

Answer:

The beat frequency is：

∴We will get a voice of 341Hz with a beat of 2Hz.

“The sound we hear would like a 341Hz (maybe a doe in doe ri mi) tune but its intensity change twice per second.”

1. **(Hecht’s 7.29)An ionized gas or plasma is a dispersive medium for EM-waves. Given that the dispersion equation is, where ωp is the constant plasma frequency, determine expressions for both the phase and group velocities and show that.**

Answer:

The phase velocity:

The group velocity:

1. **Given a Femto-second (10-15 s) laser pulse, (i.e. the duration of pulse in time, or temporal width) estimate its spectral width, i.e. the width in frequency domain. Given the central wavelength of the spectral distribution is 500 nm, what is the spectral width in wavelength? Was** **it able to excite Sodium transition around 580 nm?**

Answer:

The central frequency of the spectral distribution:

The spectral width in wavelength:

∴It’s able to excite Sodium transition.

“, this is broad and no approximation can be made. The center frequency is 500nm which is, so the lower end in frequency spectrum is Hz and high end is Hz, and corresponding wavelength can be calculated from 3000nm to 270nm. It certainly can excite both lines of sodium. (Note the 500nm is not the center in wavelength distribution.)”

Another answer which is wrong:

However, according to Taylor expansion:

When is large, we cannot ignore the higher-order term.

1. **Calculate the interference pattern generated by 3 points as instead of two used in Young’s experiment. The 3 points (A, B, C) are on a straight line and equal spaced (AB=BC), the receiving plane is parallel with ABC and at distance D. The A, B, C have same amplitude and initial phase. (As illuminated by a broad laser beam).**

Answer:



Using the formula (5-20) in my notes, it is straightforward to write the field at screen point P (Here we treat the E field as scalar, i.e. the amplitude points to same direction, say perpendicular to the paper):

The contributions of A,B,C are: (I also neglect the common  part)





****

****

The intensity will be:



The fringe is a bit complicated than the double slit case, however, if ,

The above is reduced to: 

When, i.e.  or  these x will have dark fringe, the interference pattern is independent of Y, so it is Stripes in double slit experiment.

1. **Two *plane* waves with same frequency, wavelength and initial phase travel with an angle 2θ between them. Let’s arrange the coordinate system as following: Wave A forms angle θ with +Z axis, and wave B forms an angle of –θ with +Z; the wave vectors k of both waves lie in the Y-Z plane; the amplitude are A0 for both waves and along the X direction.**
2. **Please write out the wave form for A and B(in terms of k,** **, A0 , θ and y, z).**

Answer:



For A, its wave vector is: 

 unit vector

Similarly:



1. **On an observing screen of x-y plane at z=0, what is the interference pattern? (i.e. intensity distribution), and what is the spacing between the adjacent maxima.**

Answer:

For points P on the screen, (x,y,0):





Maximum is when , so 

1. **In the two-slit Young’s experiment, the distance to screen is 2m and the wavelength of light used is 600 nm, and the spacing of the slits is 1mm. Now we insert a thin plate of glass (n=1.5) of thickness 0.05 mm is placed over one of the slits, what is the resulting lateral fringe displacement at the screen?**

Answer:



Here I shall use paraxial approximation, and the setup will confirm this. The interference pattern will still be stripes but will be shifted, because the center of the screen is no longer corresponding to the 0 OPL difference between A and B path. The path A will be longer by:

, comparing the case with no glass slide.

The maximum corresponding to the equal path thus will be shifted as the figure shows, path B need to be longer by exact same amount so that the optical path length (reminding you OPL is different from length) will be equal. The length between path A and B is , d=1mm and for the 0th order maximum:



The shift of the fringe thus is approximately:



1. **(Hecht’s 9.10)White light falling on two long narrow slits emerges and is observed on a distant screen. If red light () in the first-order fringe overlaps violet in the second-order fringe, what is the latter’s wavelength?**

Answer：

Red light in the first-order fringe overlaps violet in the second-order fringe:

1. **(Hecht’s 9.28)A soap film of index 1.34 has a region where it is 550.0nm thick. Determine the vacuum wavelengths of the radiation that is not reflected when the film is illuminated from above with sunlight.**

Answer:

Need to consider the half-wavelength difference! The effective OPL is 



1. **(Hecht’s 9.33)Fringes are observed when a parallel beam of light of wavelength 500nm is incident perpendicularly onto a wedge-shaped film with an index of refraction of 1.5. What is the angle of the wedge if the fringe separation is 1/3 cm?**

Answer:

1. **Hecht’s 9.33**

One arm moves x, then the difference in path length would 2x, and optical path length differs by 2nx, but n here is 1 for air.

So

The will create phase difference by: 

92 fringe shift means phase change by 

Thus: 

(Of course you can directly using OPL differs by 92 wavelengths, since every OPL differs by one wavelength is exactly same as phase differs by 2Pi)

1. **This problem I briefly discussed in the lecture, now you may give it a proof: For two waves with same amplitude A and fixed initial phase (say both =0), but different frequency ω1 and ω2, in the class I stated that if the detection time required to record the intensity τ<<2π/Δω, interference can still be observed (i.e. the intensity at certain spatial point is different from the summation of intensity). Please prove this statement. (You may prove it using the Beat equation, Hecht 7.2.1 or the same one in my notes, that at a fixed space point the averaged intensity is different than 2A2; Or use the formula for intensity of two sources and prove that the cross term is not zero)**

Answer:







For a fixed point (fixed r), the above expression can be simplified as:

, is the phase by spatial part which is fixed for a certain point and waves. This is the expression for instantaneous intensity and what we detect (record) is an average of this I over time period, limited by the time resolution of the instrument. Say the average time is , and if its much less than the time period of the cosine function, which is  in this case, then the average process: will not be zero and interference will be observed. Reversely if , the average will give zero and no interference.

1. **The figure below shows a Rayleigh refract meter to measure the refractive index. Light form coherently illuminated slits go through separate arms of length L each and recombined afterwards to form certain interference pattern. Both arms are in vacuum initially and gas would be slowly introduced into one of the arms. This will cause a shift of the interference pattern. If total of m fringes moves across the observing point while the gas was filling. Show that the refractive index of the gas n would be: .**

****

Answer:

Initially the two OPL are same for the central point on the observing screen. As gas fills in, the index refraction will cause upper OPL changes by: 

This change of OPL will cause phase difference between the two paths for the central point on the observing screen by: 

If the phase difference by 2π, there will be one fringe shift, we now know there are m fringes shifted, then: 