# 6.8.2: Interference Due to Path Difference Simulation

In this simulation the top two waves are identical but may be set to start at different locations. The bottom graph shows the sum of the two waves. Depending on the path difference the two waves may end up exactly in phase (leading to constructive interference), exactly out of phase (destructive interference) or something in between. The step thickness, $\mathrm{D}$, controlled by the slider on the lower left, determines the distance between the starting locations of the two waves.

## Simulation Questions:

1. Start the simulation with the step thickness, $\mathrm{D}$, equal to zero. Are the waves in phase? Slowly increase $\mathrm{D}$ until the waves are exactly out of phase. What step thickness causes this?
2. Reset the simulation and slowly increase $\mathrm{D}$ to find the first three thicknesses that cause destructive interference. Verify that destructive interference occurs at step thicknesses given by $1/2\lambda,\ 3/2\lambda$,and $5/2\lambda$ (find the wavelength by subtracting the $x$-location of two successive peaks of the wave).
3. Reset the simulation and enter $1.57$ for $\mathrm{D}$ (this is the case of half a wavelength path difference so the waves cancel). Increase the wave number, $k=2\pi/\lambda$, until you find the next wavelength that experiences destructive interference (don't change $\mathrm{D}$). What is the wave vector and wavelength of this wave?
4. For light, changing the wavelength changes the color. Can the same step thickness cause destructive interference for all colors? Explain.
5. The general formula for ***destructive interference due to a path difference*** is given by $\delta=(m+1/2)\lambda/n$ where $n$ is the index of refraction of the medium in which the wave is traveling, $\lambda$ is the wavelength, $\delta$ is the path difference and $m=0,1,2,3,\ldots$ What can you say about the various choices of $m$ in this equation; what physical cases do they represent (assume $n=1$ for now)?
6. This simulation starts the two waves at different locations but path differences can also occur due to reflection from a surface that has multiple layers. Imagine what would happen if this simulation represented ***monochromatic*** (single wavelength) light reflecting off a surface with two levels (waves come in from the right and reflect back to the right). In this case the path difference would be *twice* the depth of the step so $\delta=2\times D$. How would this change the results? In which case would there be no reflection from the surface? In which case would there be constructive interference?
7. For a *reflected wave* $\delta=2\times D$ is the actual path difference; a wave reflected off the surface in the top panel must travel an extra distance equal to twice the step thickness to catch up with a wave reflected off the surface in the second panel. Reset the simulation, change the step thickness, $\mathrm{D}$, to find a case of destructive interference. Now click the check box to simulate the case of reflected waves (instead of two waves starting from the left). What do you notice about the combined waves in the case of reflection?
8. A music CD has information stored on it in the form of tiny divots blasted into the surface with a laser. Suppose you see constructive interference for red light (wavelength of $650\text{ nm}$). What is the minimum ($m=0$) depth of the divots? (Hint: The path difference is twice the divot depth.)
9. Explain why you only see one particular color when looking at a small region of a CD at a fixed angle. What happens to the other colors?
10. If you look at the colors being reflected from a CD you will notice that the color changes depending on the angle. How does the path difference change as you look at the divots at different angles? (Hint: Imagine the waves in the simulation coming in at different angles instead of horizontally. Now the path difference is the hypotenuse of a triangle, one side of which is the Step height.)
11. Suppose you wanted to make a "stealth" jet plane which was non-reflective to a particular wavelength of radar. Describe one way you might try to do this by modifying the surface of the plane.
12. Some insect wings and the feathers of some birds (for example peacocks) exhibit a feature known as ***iridescence***. From a fixed angle only one color of reflected light can be seen. Explain this phenomena given the fact that insect wings and feathers consist of overlapping layers causing the surface to be multi-layered.
13. Soap bubbles show different colors at different places on the bubble. So do oil slicks on water. In both cases light reflects off the upper and lower surfaces of the layer of soap or oil. Explain the different colors in terms of path difference (Hint: draw a picture where the wall of the soap bubble is nearly the same thickness as one wavelength and explain why the path difference is twice the thickness of the soap).
14. There are two other details needed to explain the soap bubble and oil slick color phenomena completely. While the light is inside the soap or oil it travels at a different speed so the wavelength is different. This is why the index of refraction, $n$, is

included in the formula $\delta = (m + 1/2)\lambda/n$. For the case of $m = 1$ in the formula, what would happen to a wavelength which reflected from a thickness with constructive interference for an index equal to one if instead the index was equal to $1.5$?

15. The second detail for light reflecting off a soap bubble or oil slick is light reflecting from the top surface is going from a "soft" medium (air) to a "stiff" medium (soap) but the light reflecting from the bottom layer of the soap is going from a "stiff" medium (soap) to a "soft" medium (air inside the bubble). This causes a phase change of $180^{\circ}$ at the top surface but not at the bottom. If the path difference for a particular thickness of soap film was just right for destructive interference but there was a $180^{\circ}$ phase change for the top reflected wave but not the bottom reflected wave, what would happen to that color?

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