Wave Interference Module

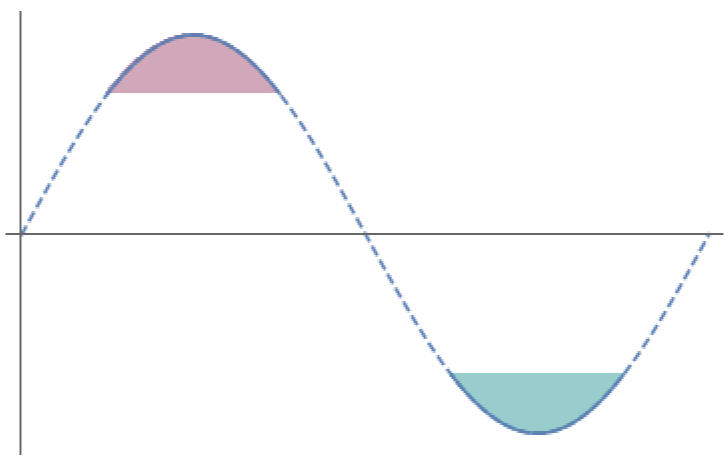
Goals:

- Graphically demonstrate constructive and destructive interference
- Discover 1D interference by adjusting wavelength and separation
- Discover relationship between interference angles, wavelength, and separation

Introduction

This module investigates wave interference graphically. When you first arrive at the website (oliverpierson.github.io), you'll see a series of concentric rings spreading out from two sources near the middle of the screen. The rings originating at a particular source correspond to circular waves flowing out from that source. We are all quite familiar with circular waves. For instance, imagine placing a ping pong ball on a still pond and rhythmically pushing it up and down. As you do so, circular waves will move away from the ball and spread out across the pond. In the animation on the webpage, you can imagine that we are pushing on two ping pong balls with the same rhythm.

You will have noticed that the rings come in two colors. Let me provide a way of associating the colors with your usual notion of a periodic wave. We all know that a periodic waves, such as a sine wave, have peaks and troughs. In the module, you can associate one of the colors with a wave peak and, similarly, associate the other color with a wave trough. The figure below illustrates this.



With the picture above in mind, you can readily see that when two rings of the same color intersect each other their peaks coincide and give rise to an even higher peak. We refer to this situation as **constructive interference**. Conversely, when two rings of different colors cross each other, the peak of one circular wave coincides with the trough of the other wave. In this case, it is as if the waves are canceling each other out at the location where they cross. We refer to this situation as **destructive interference**.

Procedures

Interference in one dimension:

1. Go to the waves website[1]. Be sure the number of sources is set to 2. All lengths in this investigation are in terms of pixels.
2. Recall that constructive interference occurs when two curves of the *same* color overlap each other. Destructive interference occurs when two curves of *different* colors overlap each other. Depending of the separation and wavelength your simulation is currently using, you may notice that constructive and destructive interference occurs at certain points on the screen but not at others.
3. Now, choose a separation distance between 10 and 100 pixels.
4. After choosing the separation, adjust the wavelength (between 15 and 50 pixels) so that constructive interference occurs on the line passing through the two sources. At this point in the investigation, we're not concerned about what is happening above/below this line. Also, you'll want to choose a wavelength *less than* the separation.
    a. Question: Does 1D constructive interference happen for more than one value of the wavelength?
    b. Question: Can you describe a mathematical relationship between the wavelength and separation when constructive interference occurs occurs on this line? (Hint: Such a mathematical relationship does exists and it is relatively simple, involving only one arithmetic operation +,-,*,/)
5. Try adjusting the wavelength so that destructive interference occurs.
    a. Consider questions 4a/b in the context of destructive interference.

Interference in two dimensions:

1. Set the separation to 30 pixels and the wavelength to 25 pixels. Then press play/pause to start the simulation over. After 3-4 seconds, pause the simulation.
2. On the screen, you will notice that at certain points two offset circles of the same color and radius intersect each other. At other points, circles of different colors intersect each other. These intersection points correspond to constructive and destructive interference points, respectively.
3. Press play to restart the simulation. After approximately 30 seconds, the circles will have filled the screen. When this happens, press pause. If you squint your eyes at the screen, you will notice that intersections of the circles from a pattern of hazy "rays" emanating from the origin (I refer to the point halfway between the sources as the origin).
4. Now choose one of the "rays" in the first quadrant where constructive interference is happening. Place your mouse cursor over a point in this ray where two circles

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[1] http://oliverpierson.github.io. If you are having issue with animation running smoothly, you can try http://oliverpierson.github.io/noanim.html.

intersect. Record the (x,y) position of your cursor. (Note: these x,y values are taken relative to the origin I referred to in part 3)

5. Now calculate: $d \sin\theta$ where d is the separation of the sources and θ is the angle between the ray and a vertical axis passing through the center of the screen (see figure below). Although, we haven't measured the angle directly, we can use the fact that $\sin\theta = x / \sqrt{x^2 + y^2}$. In other words, we are just calculating $d\, x / \sqrt{x^2 + y^2}$.
    a. Question: Does the value you've obtain look familiar? (Hint: it should!)
6. Repeat steps 4 and 5 for the ray in the first quadrant where destructive interference is occurring.
    a. Question: Does the value $d \sin\theta$ for this new point look familiar? (Hint: try multiplying it by 2)
    b. Question: How are the values of $d \sin\theta$ for the two points related?
7. Set the wavelength to 15 pixels and the separation to 60 pixels. Press play and wait for the circles to fill the screen.
8. Now repeat steps 4-5 for a few different rays of constructive interference. At this point, it may be useful to use a spreadsheet to record your data and aid your calculations.
    a. Question: You should have obtain different values of $d \sin\theta$ for all the rays. Even so, do you notice a trend in this numbers?
9. Repeat steps 4-5 for a few different rays of destructive interference.
    a. Answer questions 8a/b for the data you obtain.

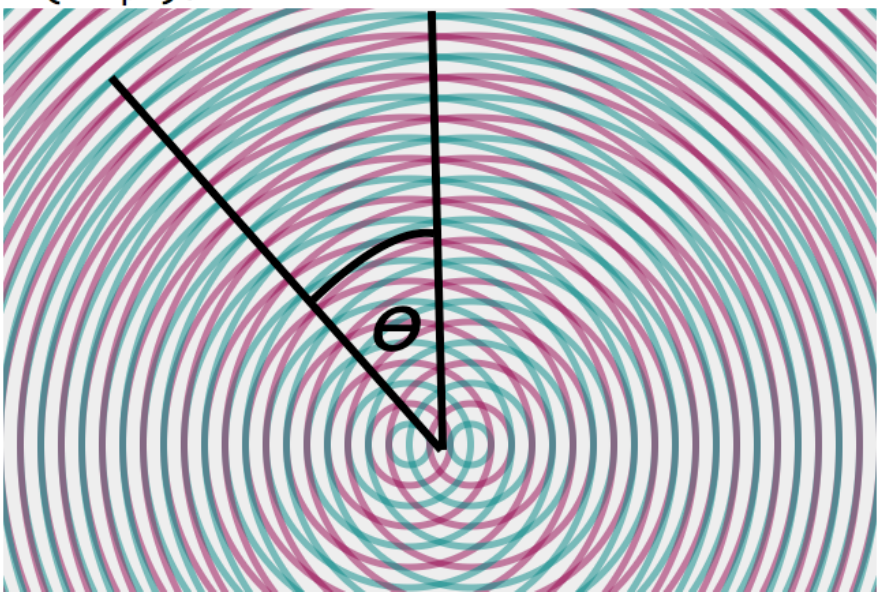
Wavelength (in px): 30

Separation (in px): 45

Number of sources: 2

X (in px): -252

Y (in px): 277



Additional Material for wave interference:

1. Goto http://oliverpierson.github.io/noanim.html. Set the wavelength to 5, the separation to 7, and number of sources to 2. You will notice a faint interference pattern on the screen. If you're having a hard time seeing the pattern, increase the number of sources to 3.
2. Count the *total* number of rays where you clearly see interference is occurring. Don't worry about differentiating between constructive and destructive.
3. Calculate $d \sin \theta$ for all the rays in one quadrant and make sketch of the rays indicating the value of $d \sin \theta$ for each ray.
4. Now, increase the number of sources by one and observe the interference pattern. Qualitatively describe the changes you observe. For example, are the "rays" becoming more or less distinct?
5. Continue increasing the number of sources and observing until you reach 10 sources.
6. Now, that you've reached 10 sources, you should see one prominent ray while the others have faded away.
    a. Question: What is the value of $d \sin \theta$ for this ray? Is there something that distinguishes this value of $d \sin \theta$ from the others? Based on this value can you see whether constructive or destructive interference is occurring?
7. Leaving the other parameters fixed, begin increasing the separation by 0.1 (be sure to press enter each time so you see the plot update) until the separation is 8. You should notice a new ray appear in each quadrant. Calculate $d \sin \theta$ for this ray (remember that d is now 8).
    a. Question: What kind of interference is occurring on this ray?
8. Now, set the number of sources back to 2 and set the wavelength to 10 and the separation to 6. As before, begin increasing the number of sources and noting again changes in the interference pattern.
9. Upon reaching 10 sources, you should notice a prominent ray as before. What do you expect $d \sin \theta$ to be for this ray? Calculate $d \sin \theta$ for this ray.
    a. Question: Did the value of $d \sin \theta$ meet your expectation? Any ideas on why or why not?