

Light and Waves – ID: 9462

By Peter Fox

Time required
45 minutes

Activity Overview

In this activity, students explore the interference patterns of waves formed by two point sources. Students are able to collect data and draw conclusions about the nodal lines formed by the interference.

Concepts

- *Constructive and destructive interference*
- *Wavelength*
- *Nodal lines*

Materials

To complete this activity, each student will require the following:

- *TI-Nspire[™] technology*
- *pen or pencil*
- *blank sheet of paper*

TI-Nspire Applications

Notes, Graphs & Geometry

Teacher Preparation

Before carrying out this activity, review with students the concept of light modeled as a wave and the concept of wave interference. You may also wish to remind students that waves can be represented in various ways, such as sine waves or concentric circles.

- *The screenshots on pages 2–6 demonstrate expected student results. Refer to the screenshots on pages 7 and 8 for a preview of the student TI-Nspire document (.tns file).*
- ***To download the .tns file, go to education.ti.com/exchange and enter “9462” in the search box.***

Classroom Management

- *This activity is designed to be **teacher-led** with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion. Note that the majority of the ideas and concepts are presented only in **this** document, so you should make sure to cover all the material necessary for students to comprehend the concepts.*
- *Students may answer the questions posed in the .tns file using the Notes application or on blank paper.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

The following questions will guide student exploration in this activity:

- What happens when two waves combine?
- How does frequency affect wave interference patterns?

Problem 1 – Interference in waves with the same frequency but different phase

Step 1: Students should open the file **PhyAct18_light_and_waves_EN.tns** and read the first two pages. Page 1.3 shows three sine curves. The thick curve represents the sum of the two dotted curves. The two dotted curves have the same frequency. Students can vary the phase shifts of the two dotted curves by moving the **p1** and **p2** sliders. Students should vary the phases of the curves and then answer questions 1–3.

Q1. What happens to the combined wave when the crests of waves **p1** and **p2** are aligned?

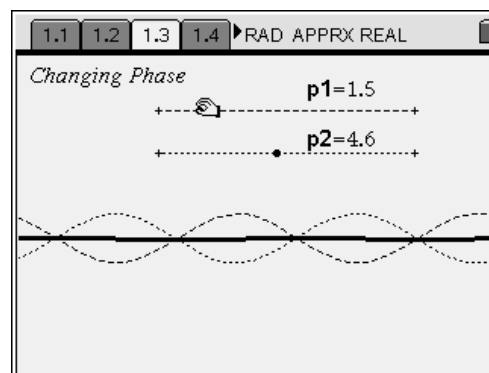
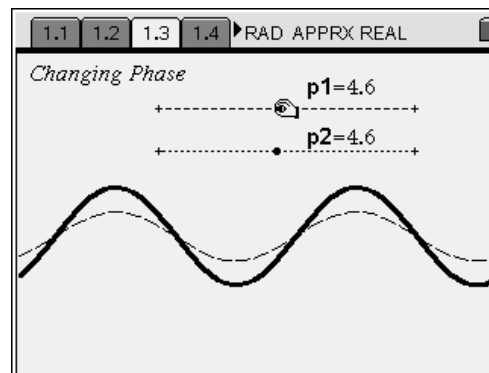
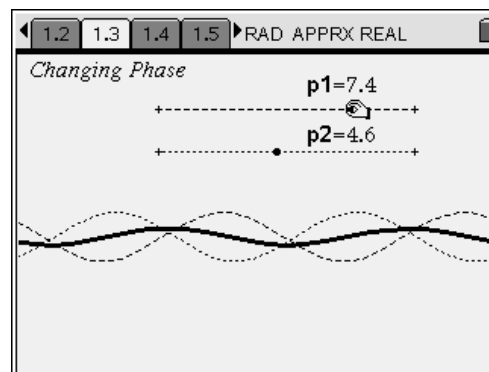
- A.** *When the crests are aligned, there is complete constructive interference, and the combined wave has an amplitude equal to the sum of the amplitudes of the two component waves.*

Q2. What happens to the combined wave when the crests of waves **p1** and **p2** are exactly opposite each other?

- A.** *When the crests are exactly opposite, there is complete destructive interference, and the combined wave has an amplitude of zero.*

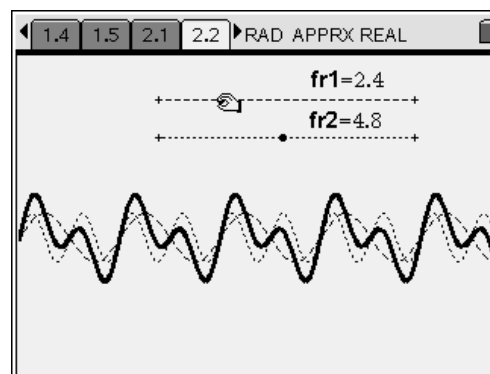
Q3. Suppose the two dotted curves represent light waves. Describe the visible effects of exactly aligning the crests and then of positioning the crests exactly opposite each other.

- A.** *Alignment of the wave crests—constructive interference—would produce a brighter light than either of the two component lights. Complete destructive interference would produce a complete lack of light.*



Problem 2 – Interference in waves with the same phase but different frequencies

Step 1: Next, students should read page 2.1 and then move to page 2.2, which is similar to page 1.3. In this case, however, the two dotted curves have the same phase but different frequencies. Students should again vary **fr1** and **fr2** and observe the results. Then, they should answer question 4.

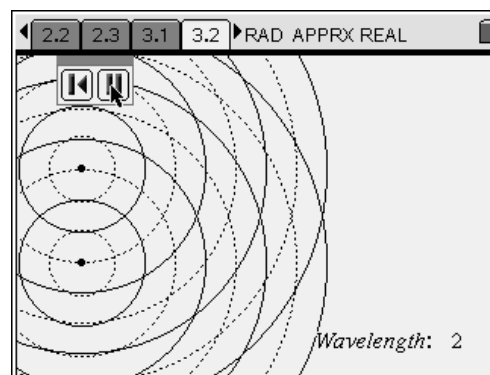


Q4. Is it possible to combine two waves with different frequencies to produce a wave with an amplitude of zero?

A. *No; if the frequencies are different, it is not possible to combine two waves to produce a net waveform with zero amplitude. The amplitude of the combined waveform will never get substantially smaller than the amplitudes of the component waves.*

Problem 3 – Interference patterns in plan view

Step 1: Next, students should read page 3.1 and then move to page 3.2. Page 3.2 shows a plan view of two interfering waves, similar to what might be observed in a ripple tank. In this simulation, dotted lines represent wave troughs, and solid lines represent wave crests. The simulation is animated; when students press the play button, the animation will begin, and the waves will propagate outward from the sources. Students should start the animation and observe how the waves interact as they move. Then, they should answer questions 5–8.



Q5. What type of interference occurs where two solid lines (wave crests) meet?

A. *Constructive interference; encourage students to discuss what they would observe if the waves were light waves (a brighter region).*

Q6. What type of interference occurs where two dotted lines (wave troughs) meet?

A. *constructive interference (a brighter region)*

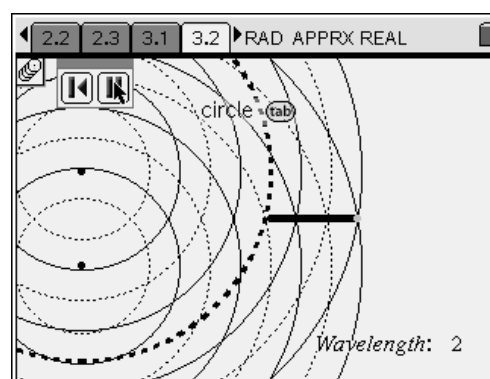
Q7. What type of interference occurs where a dotted line meets a solid line (wave trough meets a wave crest)?

A. *destructive interference (a darker region)*

Q8. What pattern do you notice in the intersections of the solid lines and of the dotted lines?

A. *The points of intersection form straight lines that radiate outward from the wave sources. At this point, you may wish to remind students of the meanings of the terms node and antinode.*

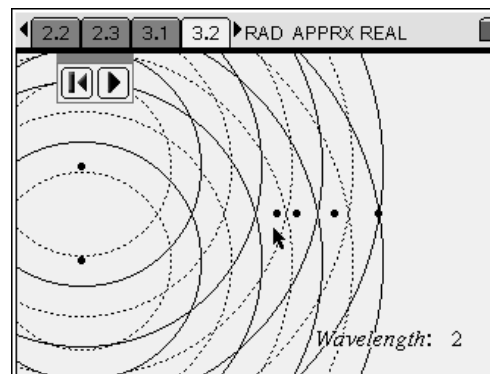
Step 2: Next, students should move back to page 3.2 and reset the animation. They should use the **Intersection Point(s)** tool (**Menu > Points & Lines > Intersection Point(s)**) to place a point on the intersection of the first two wave crests (solid lines). Then, they should use the **Geometry Trace** tool (**Menu > Trace > Geometry Trace**) to record the position of the point as the animation proceeds. To use the **Geometry Trace** tool, students should select the tool, then click on the point, and then click on the play button on the animation control. Note: Make sure students do not press **(esc)** before pressing the play button. After students have created the trace, they should answer question 9.



Q9. What path does the intersection point of the front two wave crests follow?

A. *a straight line*

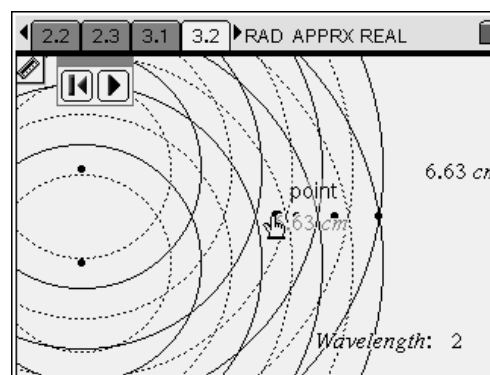
Step 3: Next, students will confirm that the node (the intersection of the two wave crests) is a straight line—that is, that it is always equidistant from the two point sources. Students should use the **Point** tool (**Menu > Points & Lines > Point**) to place several points on the geometry trace. Make sure students place the points between the wave crests and wave troughs. Then, students should delete the geometry trace (**Menu > Trace > Erase Geometry Trace**). The points should remain.



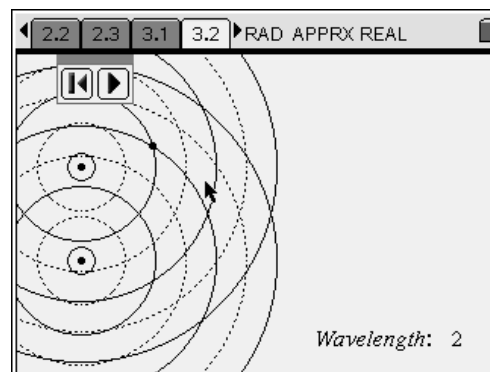
Step 4: Next, students should use the **Length** measurement tool (**Menu > Measurement > Length**) to measure the distance between each point source and each of the points they drew in step 3. Then, they should answer question 10.

Q10. Compare the distance between one point source and a point on the nodal line with the distance between the other point source and the same point on the nodal line.

A. *The distances should be equal for all points on the nodal line.*



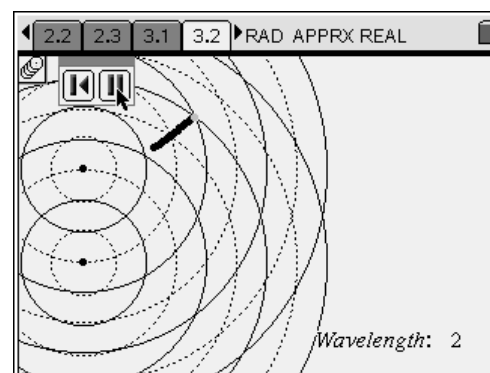
Step 5: Next, students should move back to page 3.2, reset the animation, and delete the points they created in step 3. Students will now explore the nodal lines created by the intersection of different wave crests on the two wave trains. They should use the **Intersection Point(s)** tool to mark the intersection point between the second wave crest out from one point source and the third wave crest out from the other point source, as shown to the right.



Step 6: Next, students should again use a **Geometry Trace** to record the positions of the point they marked in step 5. They should then answer question 11.

Q11. What path does the intersection point of the inner wave crests follow?

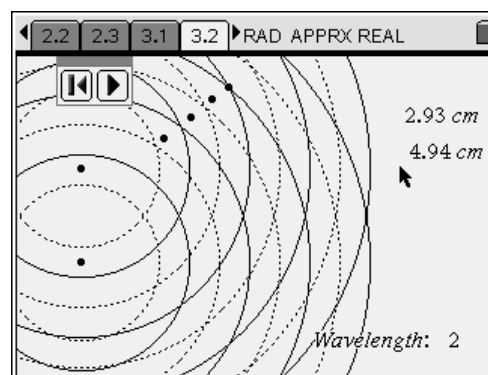
A. *The line is slightly curved, but it becomes straighter the farther from the sources it stretches.*



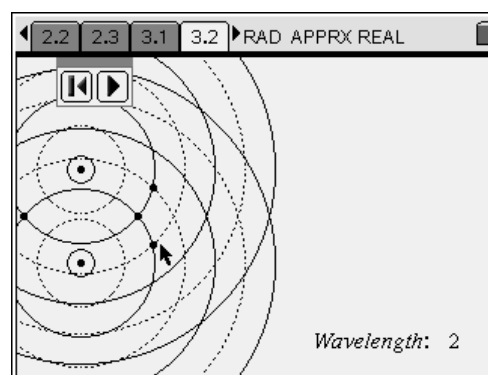
Step 7: Now, students should repeat steps 3 and 4 for the geometry trace they created in step 6. They should then answer question 12.

Q12. Compare the distance between one point source and a point on the nodal line with the distance between the other point source and the same point on the nodal line.

- A.** *The two distances differ by approximately 2 cm. Encourage students to compare this value to the wavelength of the waves, and discuss their similarity.*



Step 8: Next, students will examine the interference pattern produced by two light waves. Students should move back to page 3.2 and delete all the points they marked. Then, they should mark the intersection points between the two innermost wave crests and between the innermost wave crest on each wave and the next outward wave trough on the other wave, as shown to the right. Students should change the attributes of the points on the crest-trough intersections so they look different from the crest-crest intersection point.



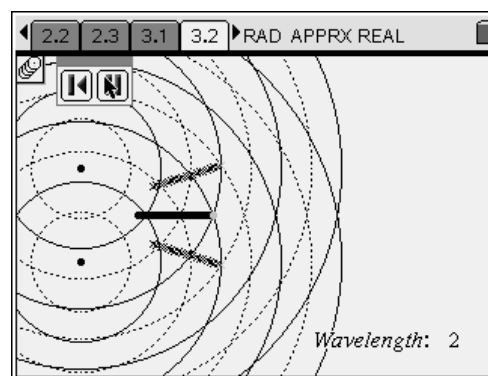
Step 9: Next, students should use the **Geometry Trace** tool to trace all three points as the animation proceeds. Then, they should answer questions 13 and 14.

Q13. What pattern do you notice in the paths of the constructive and destructive interference points?

- A.** *They alternate.*

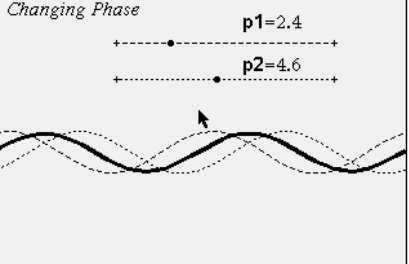
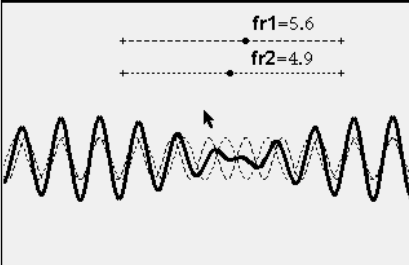
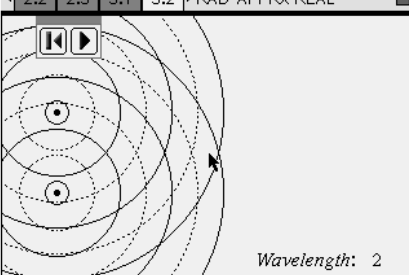
Q14. If these wave trains represented light waves, what pattern of light and dark areas would you observe when the waves interfered?

- A.** *The interference would produce alternating bands of light and dark.*



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(Student)TI-Nspire File: *PhyAct18_light_and_waves_EN.tns*

<p>1.1 1.2 1.3 1.4 ▶ RAD APPRX REAL</p> <p>LIGHT AND WAVES</p> <p>Physics</p> <p>Interference Patterns</p>	<p>1.1 1.2 1.3 1.4 ▶ RAD APPRX REAL</p> <p>The next page shows two sine waves (represented by dotted and dashed lines) and their sum (represented by the thick line). The two sliders p1 and p2 allow you to change the phases of the respective waves. Vary the values of p1 and p2 and observe the effects.</p>	<p>1.1 1.2 1.3 1.4 ▶ RAD APPRX REAL</p> <p><i>Changing Phase</i></p> <p>p1=2.4</p> <p>p2=4.6</p> 
<p>1.1 1.2 1.3 1.4 ▶ RAD APPRX REAL</p> <p>1. What happens to the combined wave when the crests of waves p1 and p2 are aligned?</p> <p>2. What happens to the combined wave when the crests of waves p1 and p2 are exactly opposite each other?</p>	<p>1.2 1.3 1.4 1.5 ▶ RAD APPRX REAL</p> <p>3. Suppose the two dotted curves represent light waves. Describe the visible effects of exactly aligning the crests and then of positioning the crests exactly opposite each other.</p>	<p>1.3 1.4 1.5 2.1 ▶ RAD APPRX REAL</p> <p>The next page shows two waves with the same phase but different frequencies. The two sliders fr1 and fr2 allow you to change the frequencies of the respective waves. The thick line is the combined effect of the two waves. Vary the values of fr1 and fr2 and observe the effects.</p>
<p>1.4 1.5 2.1 2.2 ▶ RAD APPRX REAL</p> <p>fr1=5.6</p> <p>fr2=4.9</p> 	<p>1.5 2.1 2.2 2.3 ▶ RAD APPRX REAL</p> <p>4. Is it possible to combine two waves with different frequencies to produce a wave with an amplitude of zero?</p>	<p>2.1 2.2 2.3 3.1 ▶ RAD APPRX REAL</p> <p>The following page shows a <i>plan</i> view (i.e., a view from above) of two wave sources. Solid lines represent wave crests. Dotted lines represent wave troughs.</p>
<p>2.2 2.3 3.1 3.2 ▶ RAD APPRX REAL</p>  <p>Wavelength: 2</p>	<p>2.3 3.1 3.2 3.3 ▶ RAD APPRX REAL</p> <p>5. What type of interference occurs where two solid lines (wave crests) meet?</p> <p>6. What type of interference occurs where two dotted lines (wave troughs) meet?</p>	<p>3.1 3.2 3.3 3.4 ▶ RAD APPRX REAL</p> <p>7. What type of interference occurs where a dotted line meets a solid line (wave trough meets a wave crest)?</p> <p>8. What pattern do you notice in the paths of the constructive and destructive interference points?</p>

<p>3.2 3.3 3.4 3.5 ▸ RAD APPRX REAL</p> <p>9. What path does the intersection point of the front two wave crests follow?</p> <p>10. Compare the distance between one point source and a point on the nodal line with the distance between the other point source and the same point on the nodal line.</p>	<p>3.3 3.4 3.5 3.6 ▸ RAD APPRX REAL</p> <p>11. What path does the intersection point of the inner wave crests follow?</p> <p>12. Compare the distance between one point source and a point on the nodal line with the distance between the other point source and the same point on the nodal line.</p>	<p>3.4 3.5 3.6 3.7 ▸ RAD APPRX REAL</p> <p>13. What pattern do you notice in the path of the constructive and destructive interference points?</p> <p>14. If these wave trains represented light waves, what pattern of light and dark areas would you observe when the waves interfered?</p>
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