Bell Ringer: Addition of Waves – ID: 13656

Time required
15 minutes

Topic: Waves
- *Describe the waveforms that result when different waves are added.*

Activity Overview
In this activity, students will use equations to model transverse sinusoidal waves. They will add various waves together and observe the resulting waveforms. They will use their observations to make generalizations about the effects of adding waves.

Materials
To complete this activity, each student will require the following:
- *TI-Nspire™ technology*
- *pen or pencil*
- *blank sheet of paper*

TI-Nspire Applications
Graphs & Geometry, Notes

Teacher Preparation
Before carrying out this activity, review with students the equations for sinusoidal waves and the components of those equations that represent amplitude and frequency.

- *The screenshots on pages 2–4 demonstrate expected student results. Refer to the screenshots on pages 5 and 6 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains sample responses to the questions posed in the student .tns file.*

- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter "13656" in the search box.***

- *This activity is related to activity 12255: Sound Beats. If you wish, you may extend this bell-ringer activity with the longer activity. You can download the files for activity 12255 at education.ti.com/exchange.*

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.*

- *If you wish, you may modify this document for use as a student instruction sheet. You may also wish to use an overhead projector and TI-Nspire computer software to demonstrate the use of the TI-Nspire to students.*

- *If students do not have sufficient time to complete the main questions, they may also be completed as homework.*

- *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.*
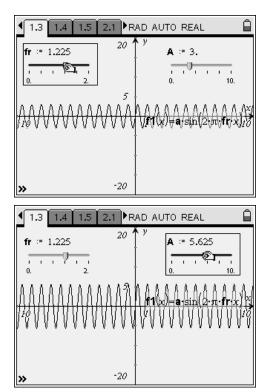
The following question will guide student exploration during this activity:

- What waveforms are produced when sinusoidal waves are added?

Students will graph various sinusoidal waves by plotting their equations. They will also plot the wave formed by adding those waves together. They will use their observations to make generalizations about the effects of adding waves with different characteristics.

Step 1: Students should open the file **PhysBR_week23_wave_addition.tns** and read the first two pages. Page 1.3 shows a graph of a sine wave. Students should vary the amplitude and frequency of the wave and observe the resulting waveform. (To use the sliders, students should use the NavPad to move the cursor to the slider value located below each variable. They can press ⊛ to select the slider, and then use the NavPad to drag it to change the values. Alternatively, students can use the NavPad to scroll over the text value of the variable. Students should press ⊛ twice to delete the value, and then type a new value.) After students have varied amplitude and frequency, they should answer questions 1 and 2. (Note: When the frequency of the wave approaches 2, the wave may begin to look somewhat blocky. Clarify with students that this is an artifact of the way the TI-Nspire graphs the function, not an actual characteristic of the function itself.)
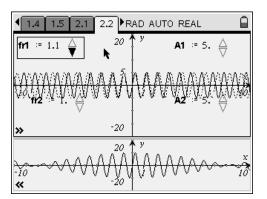
Q1. How does changing the frequency affect the shape of the wave?

  A. *As the frequency increases, the crests and troughs of the wave move closer together. Note that the x-variable on these graphs is time, not distance. Therefore, when crests and troughs move closer together, the wavelength of the wave does not necessarily change. Wavelength only changes when the velocity of the wave is held constant. What changes in this simulation is the period of the wave, not the wavelength necessarily.*

Q2. How does changing the amplitude affect the shape of the wave?

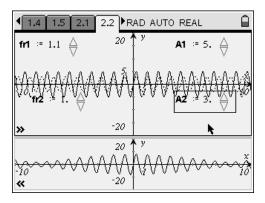 **A.** *As the amplitude increases, the height of the wave increases.*

Step 2: Next, students should read page 2.1 and then move to page 2.2, which shows two different graphs. The top graph shows two different waves (**f1** and **f2**). The bottom graph shows the sum of those two waves. Students can vary the amplitudes and frequencies of the two component waves and observe how the resulting wave changes. Then, they should answer questions 3, 4, and 5.

Q3. How does varying the amplitudes of the component waves affect the shape of the net waveform?

   A. *As the amplitudes of the component waves increase, the overall amplitude of the net waveform also increases.*

Q4. What is the shape of the net waveform when the two component waves have the same frequency?

   A. *When the two component waves have the same frequency, the net waveform has that frequency, but its amplitude is greater than the amplitudes of the component waves.*

Q5. When two waves of different frequencies are added, the amplitude of the resultant wave increases in certain areas and decreases in others. Explain why this occurs.

   A. *If the waves have different frequencies, the locations of the positive and negative regions of the two waves will not always match. When two positive or two negative regions align, the amplitude of the resulting wave increases. When a positive region aligns with a negative region, the amplitude of the resulting wave decreases.*
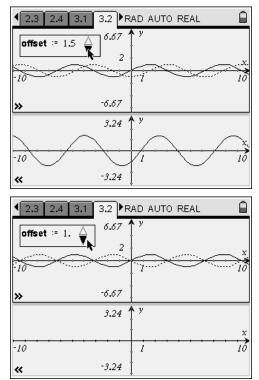
Step 3: Next, students should read the text on page 3.1, and then move to page 3.2, which again shows two component waves on the top and the net waveform on the bottom. Students should vary the value of **offset** and observe how the net waveform changes. Then, they should answer questions 6 and 7.

Q6. What happens to the shape of the net waveform as the offset changes?

A. *The amplitude of the net waveform is greatest when the offset is 0 or 2π. When the offset is exactly π, the net waveform has a zero amplitude—the component waves exactly cancel each other out. The position of the net waveform also changes as the offset changes. (You may need to remind students that **offset** is a multiplier for π in this case—that is, an **offset** value of 2 corresponds to an actual offset of 2π.)*

Q7. Noise-canceling headphones can dampen or eliminate background noise using the principles of wave addition. Explain why these headphones are generally most effective at eliminating noise with a consistent amplitude and frequency.

A. *Noise-canceling headphones work by modifying ambient noise waveforms and then playing them back to the listener. The headphones contain programming that allows them to determine the wavelength of the background noise and to generate a similar waveform that is offset by exactly π. When the new waveform is played back to the listener, it cancels out the background noise. These headphones most effectively dampen noises with consistent waveforms because the headphones must be able to generate a canceling wave in real time. If the frequency, amplitude, and other characteristics of a sound are changing rapidly—as in, for example, speech or music—the headphones cannot generate the canceling waves quickly enough. For a constant background noise, though, they can easily generate an appropriate waveform.*

Suggestions for Extension Activities: If you wish, you may have students explore the effects of varying all three factors—frequency, amplitude, and offset—on the shape of the resulting waveform. You may also have students experiment with adding more than two waves together.

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(Student)TI-Nspire File: *PhysBR_week23_wave_addition.tns*

1.1 1.2 1.3 1.4 ▶RAD AUTO REAL
_____
ADDITION OF WAVES
_____
Physics
Waves

1.1 1.2 1.3 1.4 ▶RAD AUTO REAL
A sinusoidal transverse wave can be described by an equation of the form $g(x) = A \sin(2\pi f x)$, where **A** is the amplitude of the wave, f is the frequency of the wave, and x is time. Vary the amplitude and frequency of the wave on the next page to see how these variables affect the shape of the wave.

1.1 1.2 1.3 1.4 ▶RAD AUTO REAL
fr := .925   A := 3.
$f1(x) = a \cdot \sin(2 \cdot \pi \cdot fr \cdot x)$

1.1 1.2 1.3 1.4 ▶RAD AUTO REAL
1. How does changing the frequency affect the shape of the wave?

1.2 1.3 1.4 1.5 ▶RAD AUTO REAL
2. How does changing the amplitude affect the shape of the wave?

1.3 1.4 1.5 2.1 ▶RAD AUTO REAL
When two or more sine waves are added, they produce a net waveform. The shape of the net wave depends on the characteristics of the component waves. Vary the amplitudes and frequencies of the component waves on the next page and observe the effects on the net wave.

1.4 1.5 2.1 2.2 ▶RAD AUTO REAL
fr1 := 1.   A1 := 5.
fr2 := 1.   A2 := 5.

1.5 2.1 2.2 2.3 ▶RAD AUTO REAL
3. How does varying the amplitudes of the component waves affect the shape of the net waveform?

2.1 2.2 2.3 2.4 ▶RAD AUTO REAL
4. What is the shape of the net waveform when the two component waves have the same frequency?

2.3 2.4 2.5 3.1 ▶RAD AUTO REAL
5. When two waves of different frequencies are added, the amplitude of the resultant wave increases in certain areas and decreases in others. Explain why this occurs.

2.3 2.4 3.1 3.2 ▶RAD AUTO REAL
The shape of the net waveform also depends on the displacement between the component waves. Vary the displacement of the waves on the next page and observe the effects on the net waveform. (Note: The value of **offset** on the next screen is a multiplier for π in the equations for the waves. For example, when **offset**=2, the actual offset is 2π.)

2.3 2.4 3.1 3.2 ▶RAD AUTO REAL
offset := 2.

◀ 2.5	3.1	3.2	3.3 ▶ RAD AUTO REAL 🔋

6. What happens to the shape of the net waveform as the offset changes?

◀ 3.1	3.2	3.3	3.4 RAD AUTO REAL 🔋

7. Noise–canceling headphones can dampen or eliminate background noise using the principles of wave addition. Explain why these headphones are generally most effective at eliminating noise with a consistent amplitude and frequency.