



Name: \_\_\_\_\_

Date: \_\_\_\_\_

## Student Exploration: Sound Beats and Sine Waves

**Vocabulary:** amplitude, beat, constructive interference, crest, destructive interference, frequency, hertz, sound wave, trough



**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

1. The picture at left shows water ripples interacting. What do you notice about the area indicated by the arrow?

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2. Why do you think there are no distinct ripples in the area indicated by the arrow?

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\_\_\_\_\_

### Gizmo Warm-up

Just like ripples on the surface of water, **sound waves** can interact with and influence each other. You can use the *Sound Beats and Sine Waves* Gizmo to explore two different types of sound wave interactions.

If you have headphones available, put them on now. Under **Visual**, turn on **Sound A**. Click the **PLAY** icon (  ) next to the **Sound A** slider. Listen closely to the sound. Now, click **PLAY** next to the **Sound B** slider.



1. How do the two sounds compare? \_\_\_\_\_



\_\_\_\_\_

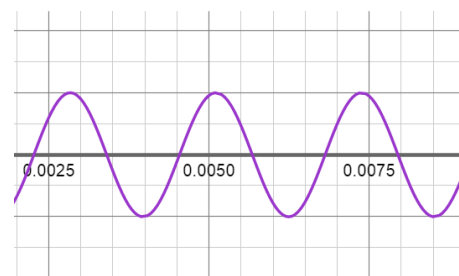
2. Click the **PLAY** icon under the word **Auditory** to play Sound A and Sound B together. How does this sound differ from Sound A and Sound B when they are played alone?

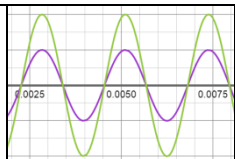
\_\_\_\_\_

\_\_\_\_\_

Sound A  440 

Sound B  440 



<b>Activity A:</b> <b>Constructive interference</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>• Make sure the <b>Frequency</b> for both <b>Sound A</b> and <b>Sound B</b> is set to 440 Hz.</li> <li>• Check that the <b>Visual</b> for <b>Sound A</b> is on.</li> </ul>	
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**Introduction:** The sine wave shown in the Gizmo represents a sound wave. **Crests**, or high points, correspond to places where air molecules are pushed together in a sound wave. **Troughs**, or low points, correspond to places where air molecules are spread apart in a sound wave. The **amplitude** of the wave is the distance between a crest or trough and the rest position on the horizontal axis.



**Question: How do two waves with the same frequency interact?**

1. **Compare:** A wave's **frequency** is the number of waves that pass a point in a given time. Frequency is measured in **hertz** (Hz), or waves per second. Sounds A and B currently have the same frequency. How do you think Sound B's sine wave will compare to Sound A's?

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Turn on the **Visual** for **Sound B** to check your answer.

2. **Observe:** Turn on the **Visual** for **Sound A + B**. What happens when these two sound waves combine? \_\_\_\_\_

3. **Make a rule:** In the Warm-up, you discovered that when Sound A and Sound B are played together, the volume of the combined sound increases. Make a rule that explains the relationship between a sound wave's amplitude and its volume:

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4. **Draw conclusions:** Turn on the **Time marker**. Position the marker over a wave crest. The amplitude of each wave is given on the bottom left side of the Gizmo screen.

A. What is the amplitude of **Sound A**? \_\_\_\_\_ **Sound B**? \_\_\_\_\_


B. What is the amplitude of **Sound A + B**? \_\_\_\_\_

C. Complete the sentence: The amplitude of **Sound A + B** is equal to the sum of \_\_\_\_\_

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When the crests and troughs of one wave overlap the crests and troughs of another wave, **constructive interference** occurs. The result of constructive interference is a new wave with higher crests and deeper troughs. Thus, the new wave has a greater amplitude than the original waves.



<b>Activity B:</b> <b>Destructive interference</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>• Turn off the <b>Visual</b> for <b>Sound A + B</b>.</li> <li>• Set the <b>Frequency</b> of <b>Sound A</b> to 441 Hz.</li> <li>• Check that <b>Sound B</b> is set to 440 Hz.</li> </ul>	
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**Question: How do sound waves interact when their frequencies are different?**

1. Compare: Play **Sound A**. Next, play **Sound B**. Can you hear any difference in the two sounds? If so, describe how the two sounds are different.

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2. Observe: Turn on the **Visual** for both **Sound A** and **Sound B**. Move the **Time** slider at the bottom of the Gizmo screen back and forth. Describe what you see.

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3. Collect data: Move the **Time** slider all the way to the left. For each of the times listed in the table below, use the **Time marker** to record the amplitudes of **Sound A** and **Sound B**. Then, find the sum of the two amplitudes and record this number in the last column. (Note: Pay attention to negative signs.)

Time (t)	Sound A amplitude	Sound B amplitude	Sound A + B amplitude
0.0006			
0.3000			
0.4995			

4. Predict: Study the data you collected. What do you think Sound A and Sound B will sound like when they are played together? \_\_\_\_\_

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5. Observe: Click **PLAY** to listen to the combined sounds. Describe what you hear: \_\_\_\_\_

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**(Activity B continued on next page)**



**Activity B (continued from previous page)**

6. Explain: Why did the volume of the sound change over time? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

7. Observe: When two waves of slightly different frequencies combine, you hear variations in the volume of the sound. The change from soft to loud is called a **beat**. Click **PLAY** to listen to the combined sounds again.


How many beats did you hear? \_\_\_\_\_

8. Identify: The loud part of the beat is the result of constructive interference. The soft part of the beat is the result of **destructive interference**, which occurs when the crest of one wave and the trough of another overlap. When destructive interference occurs, the resulting wave has a smaller amplitude than the original waves.

Turn on the **Visual** for **Sound A + B**. Move the time slider all the way to the left. For each of the following times, determine whether constructive or destructive interference is occurring:

0.0050: \_\_\_\_\_ 0.5100: \_\_\_\_\_

0.7550: \_\_\_\_\_ 2.0175: \_\_\_\_\_

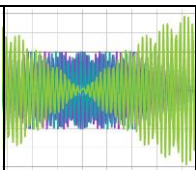
8. Make connections: Click the zoom out control () on the graph three times.

A. What do you see? \_\_\_\_\_  
\_\_\_\_\_

B. How do you think this relates to the number of beats you counted? \_\_\_\_\_  
\_\_\_\_\_

C. **PLAY** the combined sounds. How does the sound relate to the graph's green wave?  
\_\_\_\_\_  
\_\_\_\_\_



<b>Activity C:</b> <b>Frequencies and beats</b>	<u>Get the Gizmo ready:</u> <ul style="list-style-type: none"> <li>• Make sure the <b>Visual</b> for <b>Sound A + B</b> is on.</li> <li>• Make sure the <b>Frequency</b> of <b>Sound A</b> is 441 Hz, and the <b>Frequency</b> of <b>Sound B</b> is 440 Hz.</li> </ul>	
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**Question: How do the number of beats relate to the frequencies of the two sound waves?**

1. **Predict:** Do you think you will hear more beats or fewer beats if you increase the frequency difference between sounds A and B? Explain your answer.

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2. **Collect data:** In the table below, subtract the frequency of Sound B from that of Sound A. Write this number in the third column.

Turn off the **Visual** for **Sound A** and **Sound B**. For each set of frequencies, record the number of beats in 4 seconds. To do this, you can count the beats you hear and then check this value by counting the number of pinched-in areas of the green wave pattern on the graph.

Sound A frequency (Hz)	Sound B frequency (Hz)	Frequency difference (Hz)	N <sup>o</sup> . of beats in 4 seconds	N <sup>o</sup> . of beats in 1 second
441	440			
442	440			
443	440			
443	439			
443	438			
443	437			

3. **Calculate:** Divide the number of beats in 4 seconds by 4 in order to find the number of beats per second. Use this figure to fill in the last column of the table.
4. **Analyze:** What relationship do you see between the frequency difference and number of beats in 1 second? \_\_\_\_\_
5. **Apply:** Suppose a sound wave with a frequency of 444 Hz combined with a sound wave with a frequency of 436 Hz. How many beats would you hear in one second?

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