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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1. 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? \_\_\_\_\_\_\_\_\_

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1. 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?

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| **Activity A:** **Constructive interference** | Get the Gizmo ready: * Make sure the **Frequency** for both **Sound A** and **Sound B** is set to 440 Hz.
* Check that the **Visual** for **Sound A** is on.
 | 524SE2 |



**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.

1. Observe: Turn on the **Visual** for **Sound A + B**. What happens when these two sound waves combine? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. 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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1. 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.
2. What is the amplitude of **Sound A**? \_\_\_\_\_\_\_\_\_\_\_\_\_\_ **Sound B**? \_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. What is the amplitude of **Sound A + B**? \_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. Complete the sentence: The amplitude of **Sound A + B** is equal to the sum of \_\_\_\_\_

 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

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.

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| **Activity B:** **Destructive interference** | Get the Gizmo ready: * Turn off the **Visua**l for **Sound A + B**.
* Set the **Frequency** of **Sound A** to 441 Hz.
* Check that **Sound B** is set to 440 Hz.
 | 524SE3 |

**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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1. Observe: Turn on the **Visua**l 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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1. 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.)

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

1. 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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1. 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)**

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

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1. 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? \_\_\_\_\_\_\_\_\_\_\_

1. 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 **Visua**l 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: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Make connections: Click the zoom out control () on the graph three times.
2. What do you see? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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

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1. **PLAY** the combined sounds. How does the sound relate to the graph’s green wave?

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| **Activity C:** **Frequencies and beats** | Get the Gizmo ready: * Make sure the **Visua**l for **Sound A + B** is on.
* Make sure the **Frequency** of **Sound A** is 441 Hz, and the **Frequenc**y of **Sound B** is 440 Hz.
 | 524SE4 |

**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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1. 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.

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| --- | --- | --- | --- | --- |
| **Sound A frequency (Hz)** | **Sound B frequency (Hz)** | **Frequency difference (Hz)** | **No. of beats in 4 seconds** | **No. of beats in 1 second** |
| 441 | 440 |  |  |  |
| 442 | 440 |  |  |  |
| 443 | 440 |  |  |  |
| 443 | 439 |  |  |  |
| 443 | 438 |  |  |  |
| 443 | 437 |  |  |  |

1. 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.
2. Analyze: What relationship do you see between the frequency difference and number of beats in 1 second? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. 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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