Lab 12:
Sound Waves

College Physics For AP® Courses

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In this lab you will learn

- to use graphs of waveforms to see how waves can constructively and destructively interfere based on how they overlap
- to design a suitable experiment and analyze data illustrating the superposition of mechanical waves—only for pulses or standing waves
- to design a plan for collecting data to determine the exact means of interference of two waves

Activity 1: Pre-Assessment

1. How are frequency, velocity, and wavelength related? What are harmonics and how do they relate to a specified frequency? Do you think the temperature of the medium impacts the results?
2. Using what you know of harmonics, how could you use a tuning fork (or several) and a cylinder partially filled with an adjustable amount of water to determine the speed of sound? What data would you need to collect? Design a data table and draw it in your notebook.
3. **Discuss the answers to questions 1 and 2 with the class.**

Activity 1: Speed of Sound

Sound traveling through a cylinder closed at one or both ends will resonate at specific wavelengths related to the frequency of the sound produced. A tube partially filled with water is an example of a closed cylinder because the water surface reflects the sound wave. Closed tubes have a fundamental resonance at a length that is ¼ of the wavelength, with additional resonances each at ½ wavelength intervals. See Figure 12.1.

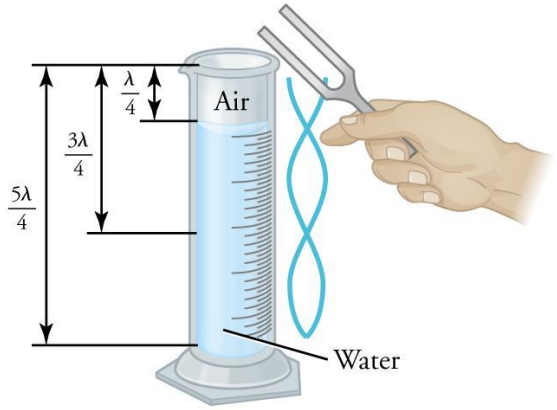


Figure 12.1: Resonances occur when the length of the column of air above the water is the correct multiple of the wavelength.

Resonant frequencies can be identified by listening to the sound coming from the top of the graduated cylinder while setting the air inside into vibration at a specific frequency. Each frequency corresponds to a specific wavelength because of the relationship

$$\lambda = \frac{l}{f}$$

When the length of the air column does not match a resonant wavelength, you will have interference breaking down the wave and the sound will be muted. When the length of the air column matches the correct multiple of the wavelength for the specified frequency, you will hear a greatly increased sound volume.

Safety Precautions

- Inform your teacher immediately of any broken glassware, as it could cause injuries.
- Clean up any spilled water or other fluids to prevent slips and falls.

For this activity, you will need the following:

- Graduated cylinder
- Water
- Tuning forks of various frequencies
- Ruler in cm
- Thermometer

For this activity, you will work *in pairs*.

Structured Inquiry

Step 1: Determine the frequencies of the tuning forks available to you. Knowing the various frequencies, find the first three harmonics. Add these values to the data table for your measurements and show your calculations in your notebook.

Step 2: Hypothesize/Predict: Knowing the frequency of the tuning fork and that the speed of sound is roughly 300 m/s, hypothesize ¼ of the wavelength to be used as the height of the air column. Add your predictions to the data table you created in Step 1.

Step 3: Student-led Planning: You will now find the air column height, and resultant water level, for the first three harmonics of each tuning fork using Figure 12.1 as a reference. Discuss with your partner how best to set up your graduated cylinder to find the resonant frequencies.

Step 4: Critical Analysis: Record the air column height and related wavelength for each tuning fork and harmonic. Calculate the speed of sound from your data to the nearest tenth of a m/s. Are the predictions you made in Step 2 supported by your data? Why or why not? Is the speed of sound you measured close to the speed of sound for the temperature and air pressure in your classroom? (This information can be found online if you know the temperature of your classroom.) Calculate the percent error. How could you improve your results? Discuss your answers with your partner and write them in your notebook.

Guided Inquiry

Step 1: Hypothesize/Predict: Now that you know the speed of sound for the air of your classroom, find a song that has 3 – 4 simple notes and print out the notes for your reference. If you need help with this task, ask your instructor for assistance. Write your song or part of your song in your notebook. You should have at least five measures of notes.

Step 2: Student-led Planning: Submit your chosen song to your teacher. Once your teacher approves, determine which frequencies create those notes. Your teacher may allow you access to an online music synthesizer or other instrument. Once you have determined the frequencies of the three notes, find their related wavelengths in a closed column. Write all your results in your notebook.

Step 3: Using your calculated values, create your 3 – 4 notes by filling water bottles with water to the correct levels. Test your notes by blowing across the tops of the partially-filled water bottles. If possible, make a recording of your song on a cell phone or other device and use it to adjust the notes until they are as close as possible to your chosen song. Then, play your song and see if your classmates can guess it. See Figure 12.2 to identify how your setup might look.

Step 4: Critical Analysis: Were you successful at creating all of your notes and playing your song? Could your classmates identify the song? Which notes were easier to create and why do you think this was the case? Would a different size bottle have made this easier? Discuss your answers with your partner and write them in your notebook.



Figure 12.2: Bottles filled to different heights with liquid can be used to play music by producing sounds of specific frequencies.

Assessments

1. Assuming a student is using a graduated cylinder, find the first three resonant frequencies of each tuning fork in a and b below. Also, what are the related air column lengths that the student should adjust to find these resonant frequencies? Assume that the speed of sound is 343. m/s.
    a. Assume the tuning fork has a frequency of 400. Hz.
    b. Assume the tuning fork has a frequency of 700. Hz.
2. What limits how many harmonics you can create using the setup in this lab?
3. Describe why the closed tube resonates at ¼ of the wavelength. Use a diagram to help your explanation.