15160 Resonance Tube Set

CONTENTS

- *Included*
  - (1) Long Tube
  - (1) Short Tube
  - (1) Styrene Plug
  - (1) Tuning Fork, 512 Hz
  - (1) Rubber Mat, 3" diameter
- *Suggested Accessories*
  - Tuning Forks (other frequencies)
  - (1) Oscilloscope
  - (1) Microphone Setup

SAFETY

- After use, store this apparatus in a closet or cabinet; do not leave this apparatus on the floor, where it may present a slipping hazard.
- Before using an oscilloscope, inspect the oscilloscope for any sources of electric shock (bare wiring, short circuitry, etc.). Never use an oscilloscope that is open or that has any exposed circuitry.
- When using the tuning forks, strike them ONLY on the rubber mat that is provided. Do not hit the tuning forks on a solid surface, such as the table top, as this may damage the tuning fork or the table.
- Wear appropriate eye protection while performing these experiments.

PURPOSE

- To study resonance of sound waves in an open or closed column of air by making adjustments to the length of the column.

STANDARDS

The student will show evidence of the following criteria from the National Science Education Standards (NSES) for grades 5-12. Also, for more specific standards, consult the educational standards that apply to your state or province.

- Content Standard A (Grades 5-12):
  - Abilities necessary to do scientific inquiry.
    (*Resonance tube set helps students explore methods of conducting scientific inquiry regarding the nature of sound waves.*)
  - Understandings about scientific inquiry.
    (*Resonance tube set is a tool which allows for investigation of resonance of sound waves.*)

ASSEMBLY

- To construct the resonance tube needed in Procedure A, leave the styrene stopper out of the long resonance tube. Place the smaller tube inside the longer tube. To adjust the total length of the tube, pull the smaller tube out of the longer tube slowly, or push the smaller tube into the longer tube slowly.
- To construct the resonance tube needed in Procedure B, place the styrene stopper in one end of the long resonance tube. Follow the instructions above to adjust the length of the tube.
- To conduct Procedure C, allow an instructor to connect a microphone to an oscilloscope. Follow the instructions above to create an open resonance tube and a closed resonance tube.

TIME REQUIREMENT

- Initial setup with this apparatus can be completed in no more than 5 minutes.
- Each procedure in this instruction manual can be completed in 30-40 minutes.

NOTES TO THE INSTRUCTOR

On Tuning Forks.

While a 512 Hz tuning fork is included with this apparatus, it is useful to have several different tuning forks on hand for these experiments. With several different tuning forks, students can find several lengths where sound will resonate in the resonance tubes. When selecting tuning forks for use, use an electronic tuner, or a multimeter with the capability of measuring frequencies, to find your most accurate tuning forks.

On Oscilloscopes.

A working oscilloscope with a microphone can be used to graphically represent sound waves. If an oscilloscope is available for your use, your students will not only be able to see a graphical representation of sound waves, but they will also be able to see the effects of resonance on sound waves by comparing sound intensities as they adjust the length of the resonance tube.

Most oscilloscopes have two channel inputs; both of these inputs are usually BNC jacks. Microphones generally operate with ¼" or ⅛" mono plugs; you will have to purchase one or two appropriate adapters per microphone from an electronic parts store in order to adapt these connectors to a BNC connector. After connecting a microphone to the oscilloscope, you may need to adjust the voltage scale (usually a 'Volts/Div' knob) and the time scale to see a signal on your oscilloscope. If you cannot register a discernible wave pattern on your oscilloscope, you may need to use an amplifier to amplify the signal from the microphone.

SUGGESTIONS FOR USE

- Strike any tuning forks on a table or lab bench, using the included rubber mat to protect tuning forks from bending or warping.
- Before using any tuning forks, use a musical tuner or a multi-meter with frequency measuring capability to tune any tuning forks used in this experiment. See the Note to the Instructor on tuning forks for more suggestions.
- See the Note to the Instructor on oscilloscopes for suggestions on how to use an oscilloscope in this experiment.

PROCEDURE A (BRIEF DESCRIPTION)

In this procedure, students will use the large resonance tube (open on both sides), the smaller inner tube, and tuning forks to observe open-tube resonance. In particular, students will use the inner tube to adjust the length of the resonance tube, to observe how sound of a particular wavelength behaves in tubes of different lengths.

ANSWERS (PROCEDURE A)
(*Note: All calculations are assuming an air temperature of 20° C, and an air pressure of 1 ATM.*)

Q1. What does the tuning fork sound like when it is held close to the open tube? Is its sound made louder or softer by the tube?

Student answers will vary, depending on their interpretation of the sound they hear from the tuning fork. With the 512 Hz tuning fork and the tube included with this apparatus, students should notice that the sound from the tuning fork is amplified slightly.

Q2. Is there one tube length where the tuning fork sounds the loudest?

For the 512 Hz tuning fork, the tuning fork should resonate (sound the loudest) at a length of around 33.5 centimeters for the open tube.

Q3. Is there one tube length where the tuning fork is quietest, or doesn't sound at all?

Student answers will vary. Tuning forks will not resonate if a quarter of their wavelength, or a whole number multiple, is the length of the tube.

Q4. Do the other tuning forks that you used for this experiment resonate at the same tube lengths, or different tube lengths?

Student answers will vary, depending on the frequencies of the tuning forks used for this experiment. At a length of 33.5 centimeters (the resonant length for the 512 Hz tuning fork), tuning forks that are whole number multiples of 512 Hz (1024 Hz, 1536 Hz, etc.) will resonate in the tube. Other tuning forks can resonate in the tube, but the length of the tube must be adjusted according to the formula for open-tube resonance in the Concepts section.

Q5. How does the wavelength of the sound waves emitted by the tuning forks compare to the resonant lengths of the tube?

Depending on individual student calculations for the wavelength of the sound coming from the tuning forks, the wavelength should be about twice the length of the resonance tube, when the sound resonates in that tube.

ANSWERS (ASSESSMENT A)
(*Note: All calculations are assuming an air temperature of 20° C, and an air pressure of 1 atm.*)

1. Suppose you have a 440 Hz tuning fork and an open tube that is 50 centimeters long.
a) Calculate the wavelength of the 440 Hz tuning fork.

To calculate the wavelength of the 440 Hz tuning fork, simply use the formula located in the Concepts section which relates frequency, wavelength, and the speed of sound:

$$\lambda = v/f$$

In this problem, $f = 440$ Hz, and $v = 343$ m/s. Therefore,

$$\lambda = (343 \text{ m/s})/(440 \text{ Hz}) = .780 \text{ m.}$$

b) Will the open tube cause the sound from the tuning fork to resonate? If it will not, find the amount of the tube you would need to remove in order to achieve resonance.

For open tube resonance, the length of the tube must be able to fit half of a wavelength from the sound of the 440 Hz tuning fork; in other words,

$$L = \tfrac{1}{2}\lambda.$$

In this problem, $L = .5$ m, but a tube of this length can only 'fit' a half-wavelength of this length. Half of a wavelength from a 440 Hz sound wave is .39 m, so .11 m of the open tube would have to be removed for resonance to occur.

c) What other tuning forks will resonate with the adjusted open tube?

Because open-tube resonance occurs for all harmonics, the adjusted open tube will resonate for all integer multiples of 440 Hz.

d) What tuning forks will resonate in the original open tube?

First, we know that a sound wave with a half-wavelength of .5 m will fit in the tube. (See the answer for part 'b' of this assessment.) The full wavelength of this sound wave must therefore be 1 m. Using the same formula as we used in part 'a', we can find the frequency of the sound wave:

$$\lambda = v/f$$

For this problem, $\lambda = 1$ m, and $v = 343$ m/s. Therefore, a 343 Hz tuning fork will resonate in the tube. Also, a tuning fork that is any integer multiple of 343 Hz will resonate in the tube.

PROCEDURE B (BRIEF DESCRIPTION)

In this procedure, students will use the large resonance tube (closed at one end with a styrene stopper), the smaller inner tube, and tuning forks to observe closed-tube resonance; students will also use the inner tube to adjust the length of the resonance tube, to observe how sound of a particular wavelength behaves in tubes of different lengths.

ANSWERS (PROCEDURE B)
(*Note: All calculations are assuming an air temperature of 20° C, and an air pressure of 1 atm.*)

Q1. What does the tuning fork sound like when it is held close to the open end of the tube? Is its sound made louder or softer by the tube?

Student answers will vary, depending on their interpretation of the sound they hear from the tuning fork. With the 512 Hz tuning fork and the tube included with this apparatus, students should notice that the sound from the tuning fork is amplified slightly.

Q2. Is there one tube length where the tuning fork sounds the loudest?

For the 512 Hz tuning fork, the tuning fork should resonate (sound the loudest) at a length of around 33.5 centimeters for the closed tube.

Q3. Is there one tube length where the tuning fork is quietest, or doesn't sound at all?

Student answers will vary. Tuning forks will not resonate if a quarter of their wavelength, or a whole number multiple, is the length of the tube.

Q4. Do the other tuning forks that you used for this experiment resonate at the same tube lengths, or different tube lengths?

Student answers will vary, depending on the frequencies of the tuning forks used for this experiment. At a length of 33.5 centimeters (the resonant length for the 512 Hz tuning fork), tuning forks that are odd multiples of 512 Hz (1536 Hz, 2560 Hz, etc.) will resonate in the tube. Other tuning forks can resonate in the tube, but the length of the tube must be adjusted according to the formula for closed-tube resonance in the Concepts section.

Q5. How does the wavelength of the sound waves emitted by the tuning forks compare to the resonant lengths of the tube?

Depending on individual student calculations for the wavelength of the sound coming from the tuning forks, the wavelength should be about four times the length of the resonance tube, when the sound resonates in that tube.

ANSWERS (ASSESSMENT B)
For all questions, assume the air temperature is 20° C, and that the speed of sound is 343 m/s.

1. Suppose you have a 256 Hz tuning fork and a closed tube that is 44 centimeters long. The tube has a thin foam stopper at its closed end.
a) Calculate the wavelength of the 256 Hz tuning fork.

To calculate the wavelength of the 256 Hz tuning fork, simply use the formula located in the Concepts section that relates frequency, wavelength, and the speed of sound:

$$\lambda = v/f$$

In this problem, f = 256 Hz, and v = 343 m/s. Therefore,

$$\lambda = (343 \text{ m/s})/(256 \text{ Hz}) = 1.34 \text{ m}.$$

b) Will the closed tube cause the sound from the tuning fork to resonate? If it will not, how far into the tube would you need to move the stopper to make the sound from the tuning fork resonate?

Because the wavelength of the sound waves from the 256 Hz tuning fork is 1.34 m, the sound will resonate from the closed tube at 33.5 centimeters.

c) What other tuning forks will resonate with the adjusted closed tube?

Closed tubes will cause tuning forks that are at odd, integer multiples of the fundamental frequency to resonate. Therefore, tuning forks at 768 Hz and 1280 Hz will also resonate with the adjusted closed tube.

d) What tuning forks will resonate in the original closed tube?

The original closed tube in this problem is .44 meters long. In order for sound to resonate in a closed tube, a quarter of the wavelength of the sound wave must 'fit' in the closed tube; in other words,

$$L = \frac{1}{4}\lambda.$$

In this case, L = .44 m. Therefore, the full wavelength of the sound wave must be 1.76 m. A sound wave of this wavelength can be created by a tuning fork that is tuned to 195 Hz. Also, a tuning fork that creates sound waves whose frequency is an odd integer multiple of 195 Hz will resonate in this closed tube.

PROCEDURE C (BRIEF DESCRIPTION)

In this procedure, students will observe graphical representations of sound using an oscilloscope with an attached microphone. Students will also use these graphical representations of sound to observe the difference between a resonating sound wave and a normal sound wave.

ANSWERS (PROCEDURE C)

Q1. What is displayed on the screen of the oscilloscope when the tuning fork is held close to the microphone?

When the tuning fork is held close to the microphone, the oscilloscope should display a transverse wave, which is a graphical representation of the tone given off by the tuning fork.

Q2. What happens to the wave as the sound dies down?

As the sound from the tuning fork dies down, the amplitude (peaks) of the wave shrink in size.

Q3. How did the wavelength of the wave on the oscilloscope change when you changed tuning forks? Why did it change?

The wavelength of the wave on the oscilloscope will change as tuning forks change, since your tuning forks will (presumably) be at different frequencies. For example, if you observe a 512 Hz tuning fork, and then a 256 Hz tuning fork, you will notice that the wavelength of the wave from the 256 Hz tuning fork is twice as large as the wavelength of the wave from the 512 Hz tuning fork. This is consistent with the formula in the Concepts section that relates wavelength and frequency (see page 4); because the speed of sound is the same for both waves, if frequency decrease, wavelength must increase proportionally, and vice-versa.

Q4. How does the height of the wave pulses for the resonating wave pulses compare to the height of the wave pulses for the tuning fork on its own?

The height of the resonating wave pulses should be larger than the height of the wave from the tuning fork itself.

Q5. How does the height of the wave pulses for the non-resonating wave pulses compare to the height of the wave pulses for the tuning fork on its own?

The height of the resonating wave pulses should be equal to, or slightly smaller than, the height of the wave from the tuning fork itself.