

### Activity P45: Resonant Modes and the Speed of Sound (Voltage Sensor, Power Output)

Concept	<i>DataStudio</i>	<i>ScienceWorkshop</i> (Mac)	<i>ScienceWorkshop</i> (Win)
Waves	P45 Speed of Sound 2.DS	P36 Speed of Sound	P36_MACH.SWS

Equipment Needed	Qty	Equipment Needed	Qty
Voltage Sensor (CI-6503)	1	Resonance Tube (WA-9612)	1
Patch Cords (SE-9750)	2		

#### What Do You Think?

The speed of sound can be determined by various methods. How can you calculate the speed of sound in a column of air inside a tube?



*Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.*

#### Background

For a given frequency of sound in a resonance tube, there are a variety of tube lengths at which a standing wave will be formed. Likewise, for any given tube length, there are a variety of resonant frequencies—frequencies at which standing waves will be formed in the tube. In general, if the sound frequency is many times higher than the lowest resonant frequency (the fundamental frequency) for the tube, there will be several nodes and antinodes in the standing wave. For an open tube, the distance between successive antinodes in a standing wave is one-half wavelength.

The speed of sound is the product of the wavelength and the frequency, or  $v = \lambda \times f$  where  $v$  is the speed of sound,  $\lambda$  is the wavelength, and  $f$  is the frequency.

#### SAFETY REMINDER

- Follow all safety instructions.

**THINK SAFETY**  
**ACT SAFELY**  
**BE SAFE!**

#### For You To Do

Use the 'Output' feature of the interface to drive a speaker to vibrate the air inside a Resonance Tube at a fixed frequency (1000 Hz). Use *DataStudio* or *ScienceWorkshop* to control the speaker's output frequency with the Signal Generator. Use a microphone mounted in the Resonance Tube to measure the amplitude of sound. Use the Voltage Sensor to measure the signal from the microphone. Use a piston inside the tube is used to adjust the length of the column of air inside the tube.

Use the software to display the output signal of the speaker, and the input signal from the microphone. Change the position of the piston to determine the distances between successive antinodes in the standing sound waves that occur inside the tube. Use the distance to determine the wavelength of the sound and then calculate the speed of sound.

**PART I: Computer Setup**

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Voltage Sensor DIN plug to Channel A of the interface.
3. Connect banana plug patch cords into the ‘OUTPUT’ ports on the interface.
4. Open the document titled as shown:

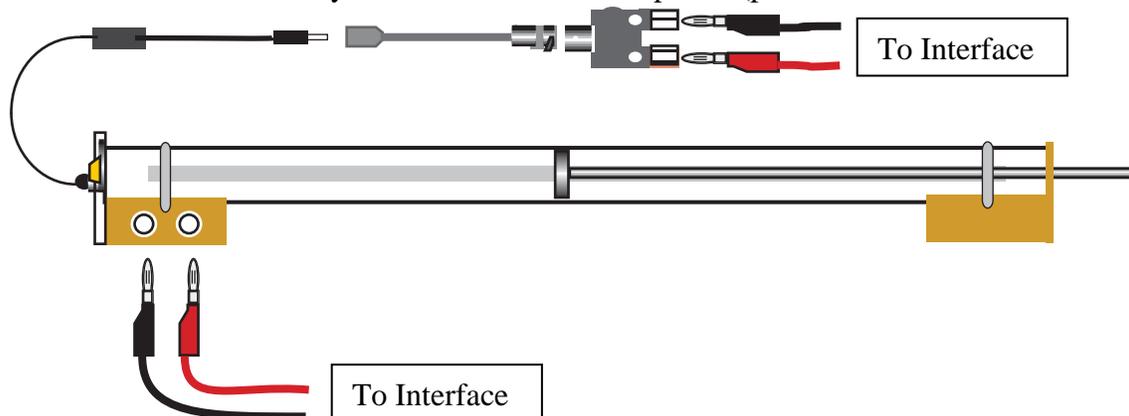


<i>DataStudio</i>	<i>ScienceWorkshop</i> (Mac)	<i>ScienceWorkshop</i> (Win)
P45 Speed of Sound 2.DS	P36 Speed of Sound	P36_MACH.SWS

- The document opens with the Signal Generator window, a Scope display, and a Frequency Spectrum (FFT) display.
- The *DataStudio* document also has a Workbook display. Read the instructions in the Workbook.
- The Scope display will show the voltage from the ‘Output’ of the interface to the speaker on the Resonance Tube and the input voltage from the microphone connected to the Resonance Tube. The Frequency Spectrum (FFT) display will show the input voltage from the microphone.
- The Signal Generator is set to produce a sine wave at 1000 Hz. It is set to ‘Auto’ so it will automatically start or stop the signal when you start or stop measuring data.

**PART II: Sensor Calibration and Equipment Setup**

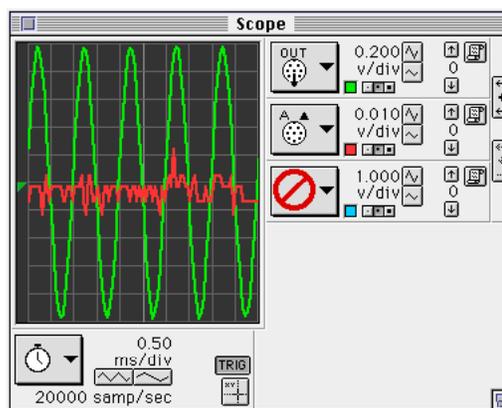
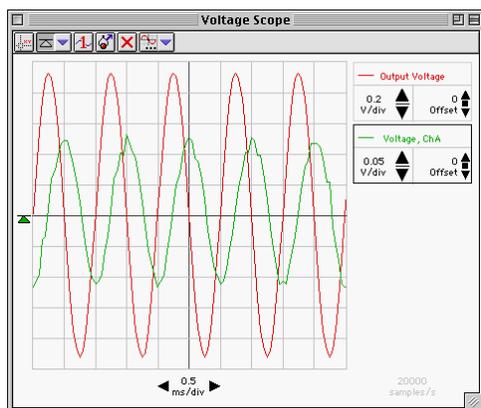
- You do not need to calibrate the Voltage Sensor.
1. Set up the Resonance Tube on a level surface. Place the piston inside the tube. Put the piston rod through the hole in the support and mount the tube into the support using the elastic cord. Position the piston at the *80 centimeter* mark inside the Resonance Tube.
  2. Connect patch cords from the ‘OUTPUT’ ports of the interface to the speaker jacks on the Resonance Tube.
  3. Make sure that a fresh battery is installed in the microphone (part number 23-115 from



- Radio Shack, or its equivalent). Place the microphone in the small hole below the speaker. Use the thumbscrew on the side of the speaker assembly to hold the microphone in place.
- Connect the microphone plug into the Mini-phone-jack-to-BNC adapter cable (included with the Resonance Tube). Connect the BNC adapter cable into the BNC ADAPTER PLUG (also included with the Resonance Tube).
  - Connect the Voltage Sensor banana plugs into the BNC ADAPTER PLUG.

### PART IIIA: Data Recording

- WARNING:** You can damage the speaker by overdriving it (increasing the amplitude too much). The sound from the speaker should be barely audible. Please keep the amplitude at 0.98 volts.



- Begin measuring data. (Click 'Start' *DataStudio* or 'MON' in *ScienceWorkshop*.)
  - The Signal Generator will begin automatically. The Scope will display the output signal from the Power Amplifier and the input signal from the microphone.
- Determine the position of the first antinode in the standing wave inside the tube. Slowly push the piston further into the tube.
  - First, listen for an increase in the sound from the speaker indicating that you have produced a standing wave in the tube.
  - Also watch the signal on the Scope display. The input signal from the microphone reaches a maximum when the length of the column of air is adjusted so there is an antinode at the microphone.
  - Finally, check the height of the fundamental frequency in the Frequency Spectrum (FFT) display.
- Adjust the piston position carefully until you are satisfied that the piston is at the point which produces the loudest sound as well as the largest signal on the Scope and FFT displays. Record the piston's position in the Data section.
- Continue moving the piston into the tube until you reach a new position where a standing wave is produced. Record this new position in the Lab Report section. Continue moving the piston until you have found all of the piston positions inside the tube that produce standing waves.
- Click the 'STOP' button to stop measuring data.

**Optional:**

Repeat the procedure for different frequencies.

**Analyzing the Data**

1. Find the average distance between each piston position. Use this distance to determine the wavelength. (Remember,  $\lambda = 2L$ .)
2. Use the wavelength and the frequency to calculate the speed of sound in air inside the tube.

**Record your data and results in the Lab Report section**

## Lab Report – Activity P45: Resonant Modes and Speed of Sound

### What Do You Think?

The speed of sound can be determined by various methods. How can you calculate the speed of sound in a column of air inside a tube?

### Data

Position	Distance (m)	$\Delta x$ (m)
1		
2		
3		
4		
5		
	Average	

Frequency = 1000 Hz

1. Find the average distance between each piston position. Use this distance to determine the wavelength.

Wavelength =        m

2. Use the wavelength and the frequency to calculate the speed of sound in air inside the tube.

Speed of sound =        m/s

### Questions

1. Use the data that you recorded to sketch the wave activity along the length of your tube with the piston in the position furthest from the speaker.

2. The theoretical value of the speed of sound in air is:

$$331.5 \text{ m/s} + 0.607 \times \text{Temperature } (^{\circ}\text{C}) \text{ m/s.}$$

For example, at Temp = 18 C, the speed of sound is 342.42 m/s. Determine the theoretical value of the speed of sound in air based on the temperature of air in your room. How does your measured speed of sound compare to the theoretical value of the speed of sound?

Name \_\_\_\_\_

Class \_\_\_\_\_

Date \_\_\_\_\_