Introduction to Waves and Resonance

Physics 102 Workshop #1 Jan. 17 – 18, 2007

Name: ______________________________ Instructor: ____________
Lab Partner(s): _______________________ Time of Workshop: _____

General Instructions

- Workshop exercises are to be carried out in **groups of three.**
- **One report per group** is due by the end of the class.
- Each week's workshop session would typically contain **three sections**. The first two sections must be completed in class. The third section should be attempted if there is time.
    1. A pre-lab reading and assignment section
    2. Experiment section
    3. Practice questions and problems

This week's workshop session has three parts. Part I introduces you to the concept of waves. Part II deals with sound waves and measuring the wavelength of sound waves. Part III deals with resonance.

PART I: Introduction to waves

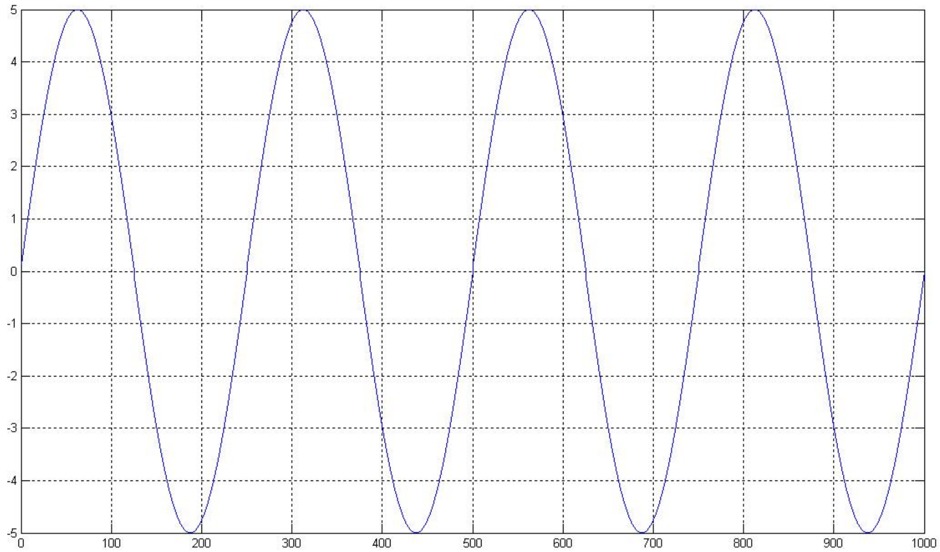
Definition

Webster's dictionary defines a wave as "**a disturbance or variation that transfers energy progressively from point to point in a medium and that may take the form of an elastic deformation or of a variation of pressure, electric or magnetic intensity, electric potential, or temperature.**"

The most important part of this definition is that a wave is a **disturbance** or **variation**, which travels through a medium. The medium through which the wave travels may experience some local oscillations as the wave passes, but the particles in the medium do not travel with the wave. The disturbance may take any number of shapes, from a finite width pulse to an infinitely long sine wave.

Waves are broadly classified as **longitudinal** and **transverse** waves. **Sound waves** are typical examples of **longitudinal** waves. As the wave passes through, the particles in the air oscillate back and forth about their equilibrium positions, but it is the disturbance that travels, not the individual particles in the medium. **String vibration** (in musical instruments like guitars) is classified as **transverse waves**. The string is displaced up and down as the wave travels from left to right, but the string itself does not experience any net motion.

To understand the concept of waves better, we would limit our discussions in this section to sinusoidal waves. The figure below shows a sine wave.



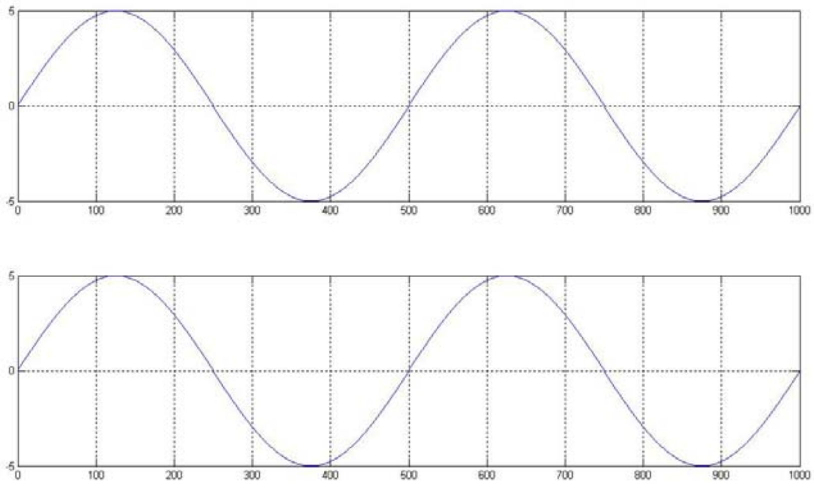
For review purposes, this wave is assumed to be a snapshot of a sound wave at a particular instant of time. This means time is constant.

1. **Label the axes** of the graph (both x and y)
2. Mark the **wave direction**
3. What is the **amplitude** of the wave?
4. What is the **distance between the crests** of the wave?
5. What is the **distance between the troughs** of the waves?
6. What is the **wavelength**?

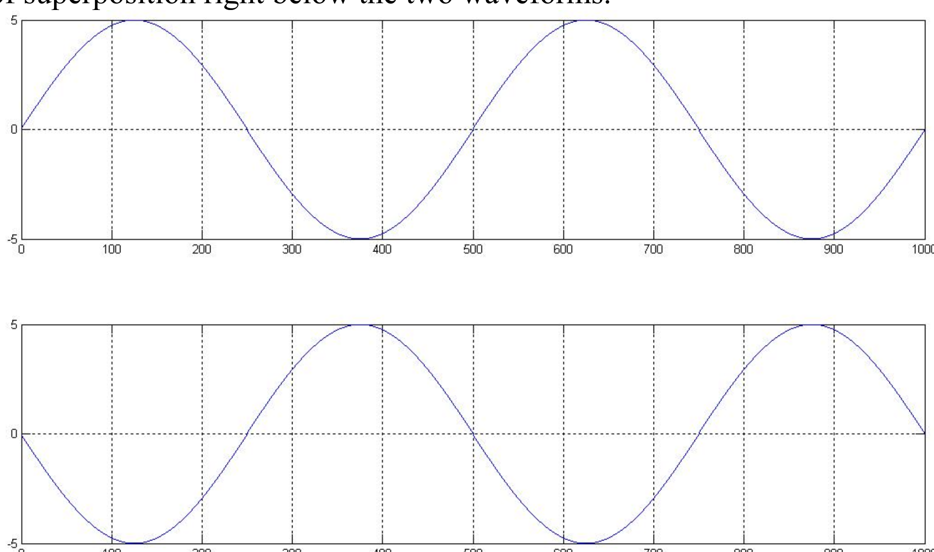
Superposition in waves

When two or more waves occupy the same space at the same time, they all add up. This is called *superposition principle*. The exercise below illustrates this.

In the figure below, the crest of the first wave overlaps with the crest of the second wave. Draw the result of superposition right below the two waveforms.



In the figure below, the crest of the first wave overlaps with the trough of the second wave. Draw the result of superposition right below the two waveforms.



By what amount (in terms of wavelength) is the second wave shifted from the two cases shown above?

The result of superposition of waves is interference. Consider two waves of the same wavelength (illustrated above).

What are the conditions for constructive interference? What is the wavelength of the resultant waveform?

What are the conditions for destructive interference?

PART II: Sound waves and measurement of wavelength

This section of the lab introduces the concept of sound waves. Sound is a wave that is created by vibrating atoms or molecules. The vibrating atoms are the atoms that compose the material in which the sound wave travels. Sound waves are longitudinal in nature. This means that the particles of the medium vibrate in a direction that is parallel to the direction in which the sound wave travels.

You would be using an oscilloscope and function generator for this part of the lab. A simple oscilloscope tutorial (used in PHY 101) is provided to help you. Please ask your TA for a demonstration if you are in doubt. Please have your connections verified by your TA before you begin your experiment. Please be extremely careful with the speaker. The speaker diaphragm is extremely sensitive. Please do not touch it.

What Range of Frequencies Can You Hear?

For this part of the lab, you would be using a function generator and a speaker. Hook up the speaker to the function generator. Turn on the function generator and set it to a sine wave with a frequency of 10Hz and Amplitude 5 V. Slowly increase the frequency (in steps of 10 till 50 Hz. Then in steps of 100 Hz. till 100 Hz. Then in steps of 1000 Hz. till you can't hear the wave) and record the frequency at which you start hearing sound and the frequency at which you can no longer hear a signal because it is too high. Write your answer below:

Minimum audible frequency:_______________ Hz.

Maximum audible frequency:_______________ Hz.

Measuring the Speed of Sound

For this part of the lab, you would be using an Oscilloscope, function generator, a speaker, a microphone, and a meter stick. **Connect speaker to the function generator**. Connect **microphone to channel #1** of the oscilloscope and the **function generator to channel #2** of the oscilloscope. Generate a pure tone (sine wave of a single fixed frequency), f (keep the frequency between 3000 Hz. and 5000 Hz. for good results), on the function generator. Select suitable signal amplitude so that it can be seen easily on the oscilloscope. Position the microphone in line with the speaker (the axes of the mic. and the speaker should be aligned) in such a way that the signal is in phase with the function generator's signal. Note the position of the microphone (in m). Move the microphone until its signal moves **four or five full periods** later/earlier. Note new position (in m). **Wavelength = difference in position / the number of periods you decided to move by**. **Wave speed = frequency * wavelength**. Repeat the above procedure for two different frequencies.

Frequency (Hz.)	Displacement (m)	displacement (λ)	Wavelength (m)	Wave Speed (m / s)

Average wave speed = ____________________ m / s.

Measuring wave attenuation of sound waves as a function of distance

Every kind of wave undergoes attenuation as a function of distance. Attenuation in simple terms is decrease in amplitude (signal strength) of the wave as it progresses along its path from source to destination. You would retain the set up from the previous part. Generate a pure tone (say 3500 Hz.) on the function generator. Select suitable signal amplitude so that it can be seen easily on the oscilloscope. Position the microphone in line with the speaker (the axes of the mic. and the speaker should be aligned) at about .02 m from the speaker. Gradually move the speaker in steps of .02m and record the amplitude of the sine wave. Plot signal amplitude as a function of distance (graph paper is in the next page).

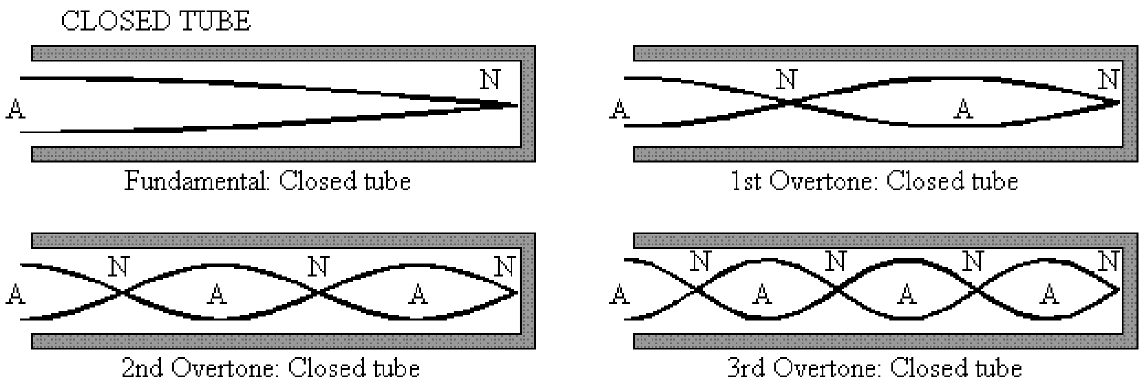
Distance (m)	Amplitude of sine wave (v)

PART III: Resonance and the Velocity of Sound

The objective of this part of the lab is to observe the resonance phenomenon in an open ended cylindrical tube. We will then use the principle of resonance to estimate the wave velocity of sound at room temperature.

In this experiment, the velocity of sound in air is to be found by using tuning forks of known frequency. The wavelength of the sound will be determined by making use of the phenomenon of **resonance** of a column of air. By *resonance*, we mean that the frequency of the tuning fork is the same as the **natural frequency** of the air column.

How do we know what are the natural frequencies of the air column? Standing waves are set up in the tube. The figure below shows how the amplitude of the sound wave changes as we move along the air column, at resonance.



The apparatus for the experiment consists of a long cylindrical plastic tube attached to a water reservoir. The length of the water column may be changed by raising or lowering the water level, while the tuning fork is held over the open end of the tube. Resonance is indicated by the sudden increase in the intensity of the sound when the column is adjusted to the proper length. The resonance is a standing wave in the air column. It occurs when the column length is: $\lambda/4$, or $3\lambda/4$, or $5\lambda/4$, etc. Here, the symbol λ represents the wavelength of the sound wave.

Required instrumentation

1. Resonance tube apparatus
2. Two tuning forks with different characteristic frequencies
3. Rubber / leather mat for striking tuning forks

Experimental strategy

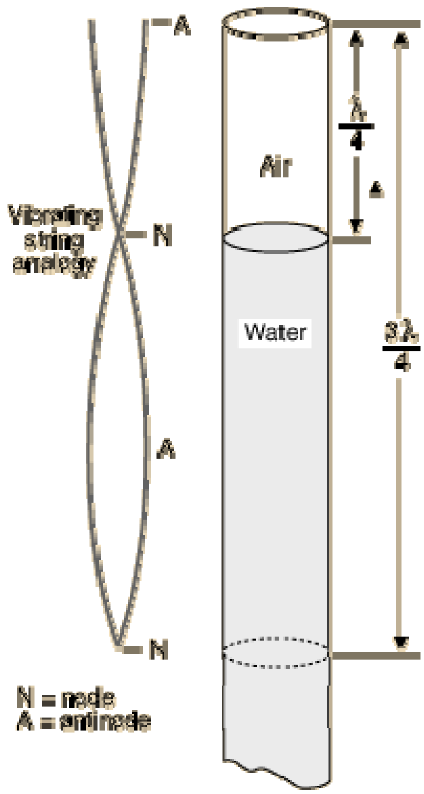
Note down all observations in the table provided.

1. Fill the tube nearly full of water. Strike one of the tuning forks on the rubber/leather mat supplied and hold it at the top of the water column. **Caution:** Do not touch the tube with the tuning fork. Do not strike the tuning fork on any other surface.

2. Using the moveable water reservoir, lower the water surface slowly, listening for amplification (loudness) of the tone. When resonance occurs, you will hear a pronounced reinforcement of the sound. Move the water surface up and down several times to locate the point of maximum sound intensity and note the length of the column (in meters).

3. Lower the water further to find the next resonant length. Continue in this manner as far as the length of the tube will permit. Obtain the lengths $\lambda/4$, $3\lambda/4$, $5\lambda/4$, … etc. (in meters) from your measurements. You will need to check to see if your column lengths follow the progression 1, 3, 5, 7, -- since you may have missed a resonance or counted one of the fainter false resonances which sometimes occur. Calculate the wavelength and velocity of sound.

4. Repeat the procedure for the other tuning fork supplied. The velocity in miles per hour may be found by multiplying the velocity in m/sec by the factor 2.24.



Observations

Room temperature (Ask your TA), **T** = _________° C.
Velocity of sound (theoretical): $\mathbf{V_{air}}$ = (331.5 + 0.6 * T) m/s = _______ m/s.

TUNING FORK FREQUENCY (HZ.)	Λ/4 (M)	3Λ/4 (M)	WAVE LENGTH (M)	VELOCITY OF SOUND (M/S)

Average velocity of sound = ______________________ m / s.