

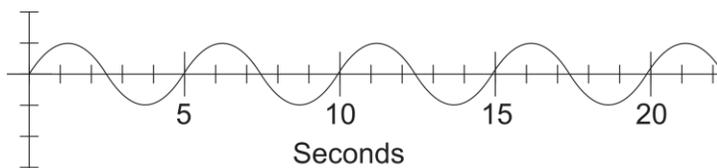
Frequency vs Period:

Frequency = # of waves/time

Period (T) = time/# of waves = time for one wavelength to pass

$f = 1/T$ $T = 1/f$

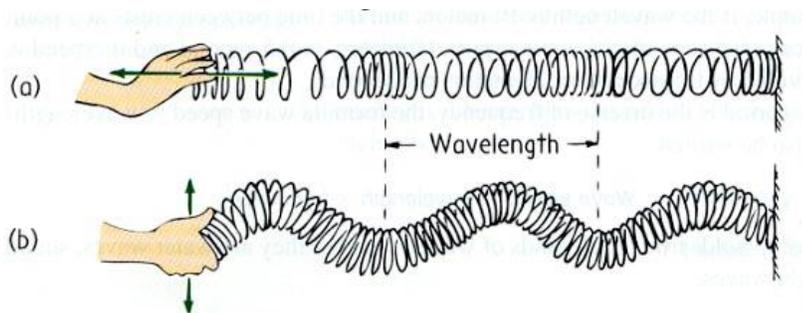
Find f and T for the wave below.



Transverse and Longitudinal Waves

- A. A transverse wave (a.k.a. shear wave, sinusoidal wave) is a disturbance _____ to the direction of propagation.
- B. A longitudinal wave (or compressional wave) is a disturbance _____ to the direction of propagation.

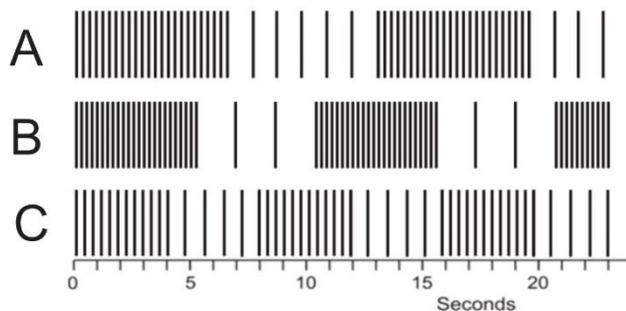
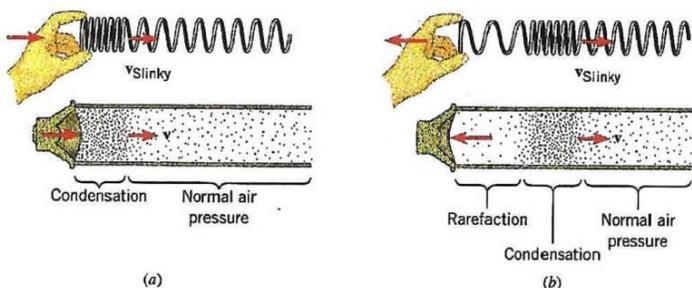
Identify the two different types of waves on the right.



Parts of a longitudinal wave: compression, rarefaction, wavelength



Formation of a sound wave (longitudinal wave, a.k.a. compression wave)



Which of the series of waves on the upper right shows the greatest amplitude?

Which is the quietest?

Find the period and frequency of wave C.

Sound waves are longitudinal, but they can be represented as transverse waves.

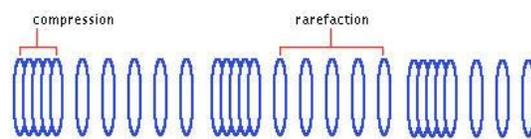


Figure 1: Longitudinal Wave

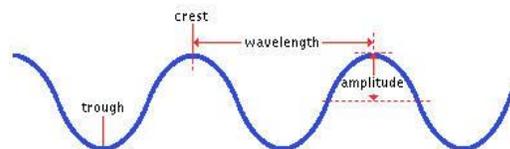


Figure 2: Transverse Wave

Speed of Sound, In Air:

The speed of sound in air depends, primarily, on _____.

You can use either of the equations below to approximate the speed of sound in air, in m/s, where T = air temperature in degrees Celsius.

$$331.3 + 0.606 T \quad \text{or} \quad v = 331.3 + \sqrt{1 + \frac{T}{273.15}}$$

Estimate the temperature in this room and calculate the approximate speed of sound:

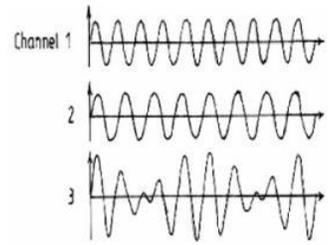
Check For Understanding:

Answer Choices: Speed, Loudness, Period, Wavelength, Density of Compressions, Density of rarefactions

1. Sound Wave A and Sound Wave B are produced in the air of the same room at the same time. If they have the same frequency but different amplitudes, which of the characteristics above may differ for the two waves?
2. Which of these characteristics (if any) change(s) as the observer moves farther away from the source? In other words, if you hear the same wave at a closer distance vs a farther distance, what changes?

Wave Interference and Beats:

Wave Interference can cause “beats”. When two waves have slightly different frequencies, their interference alternates between constructive and destructive. The diagram below shows transverse representations of two sound waves (channels 1 and 2) and their resultant sound (channel 3).



- In the diagram, label the channel with the highest frequency (1 or 2).
- Then label regions of constructive and destructive interference. Channel 3 is the “sum” of channels 1 and 2.
- Label the “beats” that will be heard

Beat frequency = difference in frequencies of two notes that are played together

Example: What is the beat frequency when 220Hz and 216Hz are played at the same time? _____

Standing Waves Revisited:

What are the rules for drawing standing waves?

- 1.
2. If an end is free to move, it is a(n) _____. If an end is fixed, it is a(n) _____.

Draw a vibrating string with the combinations of nodes and antinodes below. Take note of free and fixed ends.

- 3 nodes, 2 antinodes
- 4 nodes, 4 antinodes
- 2 nodes, 3 antinodes

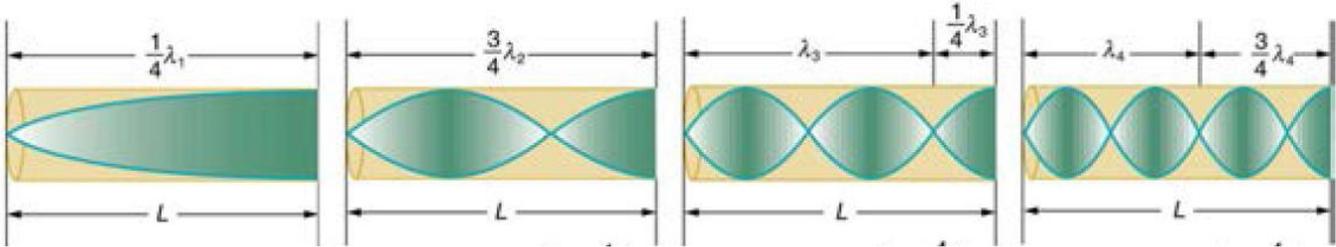
Harmonic Nomenclature:

- The “Fundamental” (a.k.a. 1st harmonic) is the standing wave pattern _____

- The 2nd harmonic (if there is one - sometimes there isn't) has a frequency that is _____ the fundamental frequency, and a wavelength that is _____ the wavelength of the fundamental. The nth harmonic has a frequency of _____ times the fundamental frequency and a wavelength equal to _____ times the wavelength of the fundamental.
- FYI, “Overtones” are all of the harmonics, beginning with the second, numbered without gaps.

Standing Sound Waves in a Tube

Wavelengths and Harmonics in a tube **open at one end** (e.g. an organ pipe)



1. What is the most important difference between standing sound waves in a pipe and standing waves on a string?
2. The diagram above represents the organ pipe waves as transverse waves. In reality, they are longitudinal. What is really happening to air molecules at the antinodes?
3. At the nodes, what are the air molecules doing?
4. For the fundamental, explain why there is a node at the left end and an antinode at the right?
5. Draw the fundamental for a pipe that is closed at both ends. How much of a wavelength does the pipe length represent?
6. On the diagram above, write an equation for wavelength in terms of tube length, for each standing wave pattern.
7. On the diagram, label the standing wave patterns with their harmonic names.
8. If you're interested, label the standing waves using the term "overtone," rather than the term harmonic.

Resonance Lab

Purpose: To measure the speed of sound using a tuning fork and resonating tube.

Setup:

1 ruler	1 meter stick
1 large graduated cylinder	1 thermometer
1 white PVC pipe	1 512 Hz tuning fork

$$v = 331.3 \sqrt{1 + \frac{T}{273.15}} \text{ m/s}$$

$$v = f\lambda$$

Procedure:

1. Measure the air temperature. Record this in the data table.
2. Calculate the speed of sound. Record this in the data table.

512 Hz First harmonic (n = 1)

3. Fill your graduated cylinder almost, but not quite, full of water with the white PVC pipe inside the cylinder. *NOTE: Do not overflow the water.*
4. Strike your 512 Hz tuning fork on one of the green rubber striking blocks. Hold it over the PVC pipe and slowly lift the pipe out of the water until you hear the pipe's first harmonic resonating with the tuning fork. Hold the pipe here, and...
5. Measure the length (L) of the PVC pipe that is above water level with the meter stick. Record this measurement in meters in the data table. *Note: Be sure to measure from the level of the water, not from the top of the graduated cylinder.*
6. Now calculate the wavelength of the sound waves when the first harmonic was produced by the 512 Hz tuning fork. Record this in the data table.
7. Next calculate the experimental speed of sound using the formula $v = \lambda f$ where λ is the wavelength calculated above in 6 above and f is the frequency of the tuning fork in Hz. Record this in the data table.
8. Finally, calculate the % error in your measurement of the speed of sound compare to the calculated speed of sound. Use the formula $\% \text{ error} = 100\% \times \frac{(\text{exp} - \text{act})}{\text{act}}$. Record this in the data table. Remember that % error can be either + or - !

512 Hz Third Harmonic (n = 3)

1. Strike your 512 Hz tuning fork on one of the green rubber striking blocks. Hold it over the PVC pipe and slowly lift the pipe out of the water past the first harmonic until you hear the next resonance. This is the third harmonic. Repeat steps 5-8 above. Record your results in the second column of the data table.

Another First Harmonic (n = 1)

2. Get a tuning fork with another frequency that is not 512 Hz. Record its frequency at the top of the third column in the table below. Repeat steps 6-9 above. Record your results in the third column of the data table.

Data Tables:

T = room temp	°C
V _{actual} (calculated from equation)	m/s

	f = 512 Hz 1st harmonic n = 1	f = 512 Hz 3rd harmonic n = 3	f = ____ Hz 1st harmonic n = 1
L _{observed}			
λ			
V _{observed}			
% error = $100\% \times \frac{(\text{observed} - \text{actual})}{\text{actual}}$			

Some Questions:

Choose one of these answers for each of the questions below.

- A. increase B. decrease C. stay the same

Use the equations we have used in class to help you answer these questions. Suppose you have a tuning fork with an adjustable frequency...

- _____ 1. If you decrease a tuning fork's frequency, what happens to its sounds' wavelength in air at a given temperature (i.e. at a given speed of sound)?
- _____ 2. If you decrease a tuning fork's frequency, what happens to the speed of its sound waves?
- _____ 3. If you were to repeat this experiment with a tuning fork having a lower frequency, how would your measured values of L change?
- _____ 4. If you were to decrease the temperature of the air, what would happen to the speed of the sound waves made by any tuning fork?
- _____ 5. If you were to decrease the temperature of the air, what would happen to the wavelengths of the sound waves made by any tuning fork?

6. How do we know that the first resonant frequency that you hear is the fundamental? You can explain with a picture.

7. As you pull the pipe from the water, you first hear the first harmonic. Next you hear the 3rd harmonic. Why did you not hear a 2nd harmonic? You can use a drawing to explain.