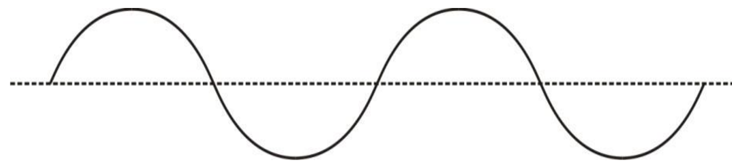
23-24 Unit 11 Handout

Name: ______________________

Waves and Sound

Label these components of a transverse wave: crest, trough, wavelength, amplitude



Wavelength:

Symbol: Formula: Units:

Frequency:

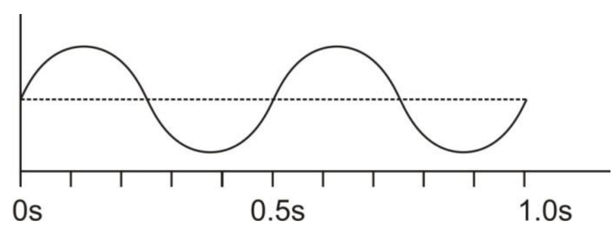
Symbol: Formula: Units:

Period:

Symbol: Formula: Units:

Wave speed Formula:

Practice: For the waves on the right, find the:



Period:

Frequency:

Speed:

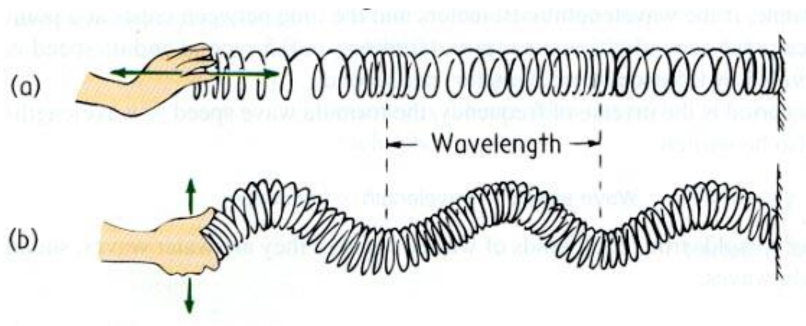
Transverse and Longitudinal Waves

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.

Types and parts of waves:

Identify the two different types of waves on the right.



Label these components of a longitudinal wave:: compression, rarefaction, wavelength

Sound Waves

1. Vibrations of an object push the medium around the object, resulting in compressions (________________ pressure regions) and rarefactions (________________ pressure regions) that move out as _______________ pressure waves.

2. Sound, like all waves, travels at a certain speed and has the properties of frequency and wavelength. The perception of frequency is called ________________.

3. The relationship of the speed of sound, its frequency, and wavelength is the same as for all waves:

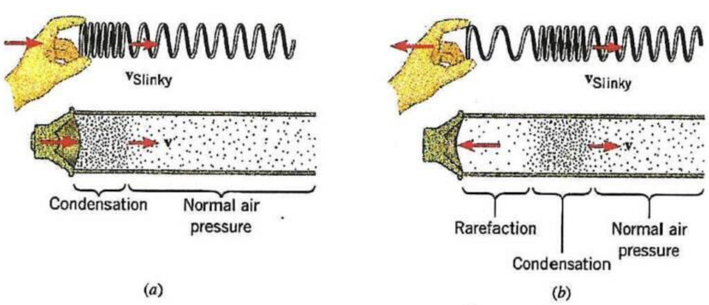
4. The speed of sound in a medium is determined by a combination of the medium's __________________ (or incompressibility) and its ___________________. The more rigid (or less compressible) the medium, the __________________ the speed of sound. The greater the density of a medium, the __________________ the speed of sound. [Analogous behaviour can be demonstrated with a ruler that is held against a desk by one end and "plucked."]

5. The speed of sound in air is low, because air is compressible. Because liquids and solids are relatively rigid and very difficult to compress, the speed of sound in such media is generally greater than in gases. As air is heated (at a constant pressure), its compressibility remains constant while its density decreases, so the speed of sound in air ____________________ with increasing temperature.

6. If T is the temperature of air, the speed of sound in that air can be approximated using:

$v = 331.3 + 0.606\,T$ <u>or</u> $v = 331.3 + \sqrt{1 + \frac{T}{273.15}}$

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



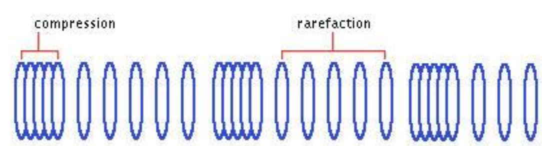


Figure 1: Longitudinal Wave

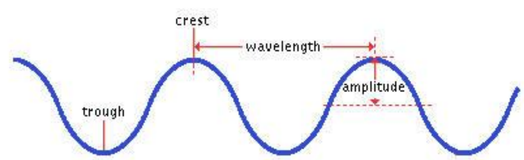


Figure 2: Transverse Wave

Practice – 17.1-17.3 Sound

1. When poked by a spear, an operatic soprano lets out a 1200-Hz shriek. What is its wavelength if the speed of sound is 345 m/s?

2. What frequency sound has a 0.10-m wavelength when the speed of sound is 340 m/s?

3. Calculate the speed of sound on a day when a 1500 Hz frequency has a wavelength of 0.221 m.

5. Air temperature in the Sahara Desert can reach 56.0°C (about 134°F). What is the speed of sound in air at that temperature?

6. A sonar echo returns to a submarine 1.20 s after being emitted. What is the distance to the object creating the echo? (Assume that the submarine is in the ocean, not in fresh water.)

Table 17.1 Speed of Sound in Various Media

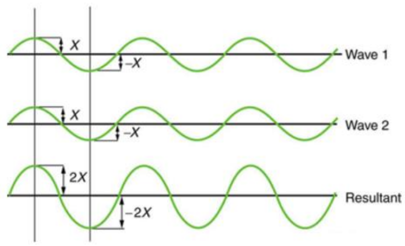
Medium	v_W(m/s)
Gases at $0^{\circ}C$	
Air	331
Carbon dioxide	259
Oxygen	316
Helium	965
Hydrogen	1290
Liquids at $20^{\circ}C$	
Ethanol	1160
Mercury	1450
Water, fresh	1480
Sea water	1540
Human tissue	1540
Solids (longitudinal or bulk)	
Vulcanized rubber	54
Polyethylene	920
Marble	3810
Glass, Pyrex	5640
Lead	1960
Aluminum	5120
Steel	5960

Answers:

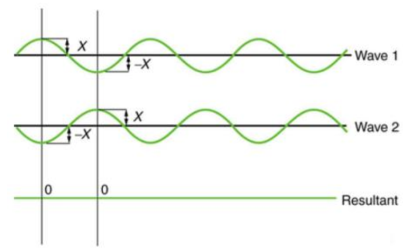
1. 0.288 m	2. 3400 Hz	3. 332 m/s
4. A. 5.96×10^3 m/s B. steel	5. 364 m/s	6. 924 m
7. 7.70 m	8. 138 m	9. 0.0179 s (5 °C) , 0.0171 s (35 °C)

Wave Interference:

1. When two or more waves arrive at the same point, the resulting wave is the _________ of the individual waves. This is a phenomenon called _____________________. If the disturbance corresponds to a force, then the forces add. Whatever the disturbance, the resulting wave is a simple addition of the disturbances of the individual waves. That is, their amplitudes add.

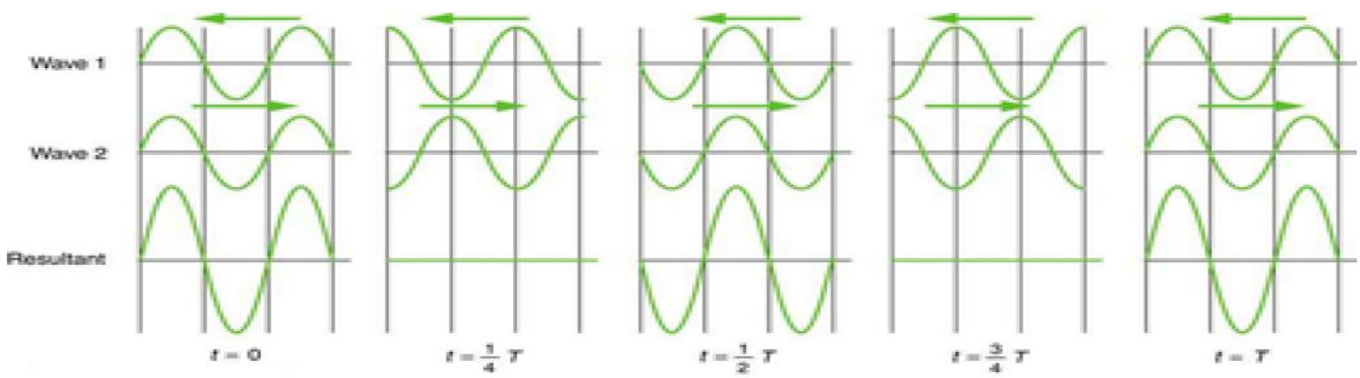


Pure _______________ Interference



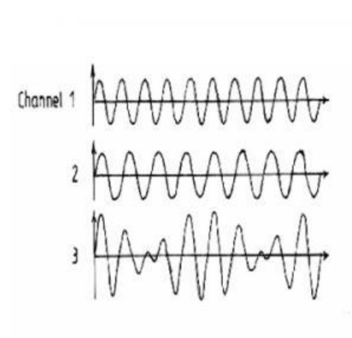
Pure _______________ Interference

2. In the diagram below, two waves pass through each other moving in opposite directions, and their disturbances add as they go by. Since the two waves have the same ____________________ and ____________________, then they alternate between constructive and destructive interference. The resultant looks like a wave standing in place. This is called a ______________________________.



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? _______

Natural Frequencies (a.k.a. resonant frequencies, harmonics, overtones)

Natural Frequency: a frequency at which a system oscillates (producing a standing wave pattern) when not subjected to an outside force; natural frequency depends on factors such as the speed of sound in the object and the object's size and shape.

Resonance: The vibration of an object at one of its natural frequencies due to an external force applied cyclically at that same frequency. (e.g. a glass being shattered by a human voice)

Fundamental Frequency (a.k.a. the Fundamental): the lowest natural frequency of an object

Harmonics: some objects, such as guitar strings, can have several natural frequencies. A harmonic is a natural frequency that is some whole number multiple of the fundamental. Harmonics are named according to this multiple: 1^{st} harmonic = the fundamental; 2^{nd} harmonic has twice the frequency of the fundamental…

Overtones: not all objects can produce standing waves at every harmonic. After the fundamental, the next lowest harmonic that can actually exist is called the 1^{st} overtone. The next is the 2^{nd} overtone…

Standing Waves:

Standing waves have patterns of nodes and antinodes. What are nodes and antinodes?

Node:

Antinode:

Two Guidelines 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) __________________.

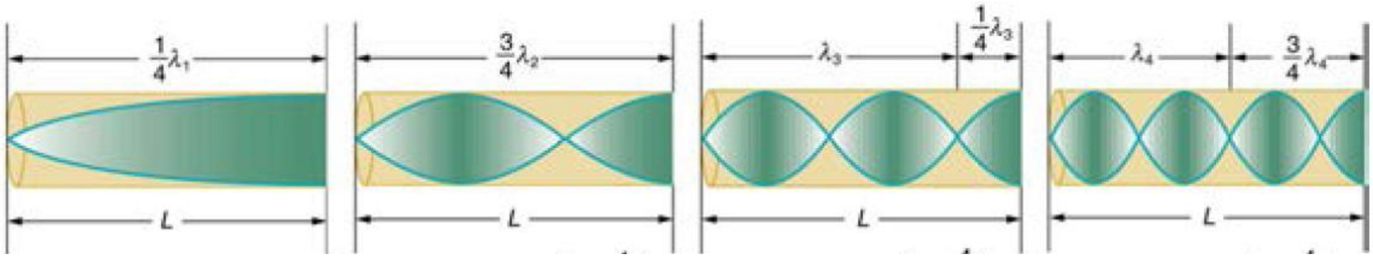
Draw a vibrating string with the combinations of nodes and antinodes below. Label the free and fixed ends.

- 3 nodes, 2 antinodes

- 4 nodes, 4 antinodes

- 2 nodes, 3 antinodes

Standing Sound Waves in a Tube Open At One End



1. How are waves in an organ pipe different than waves on a string?

2. The previous diagram represents the organ pipe waves as transverse waves. In reality, they are longitudinal. What is really happening to air molecules at the antinodes?

3. What is happening at the nodes?

4. The **fundamental** is the mode of standing waves with the longest possible wavelength. For the fundamental, explain why there is a node at the left end and an antinode at the right.

5. On the diagram…
   a. For each harmonic, write an equation for wavelength in terms of tube length.
   b. For each harmonic, write an equation for frequency, in terms of wavelength and wave speed (v)
   c. Label the harmonics and overtones in the diagram.For each harmonic, write an equation for wavelength in terms of tube length.

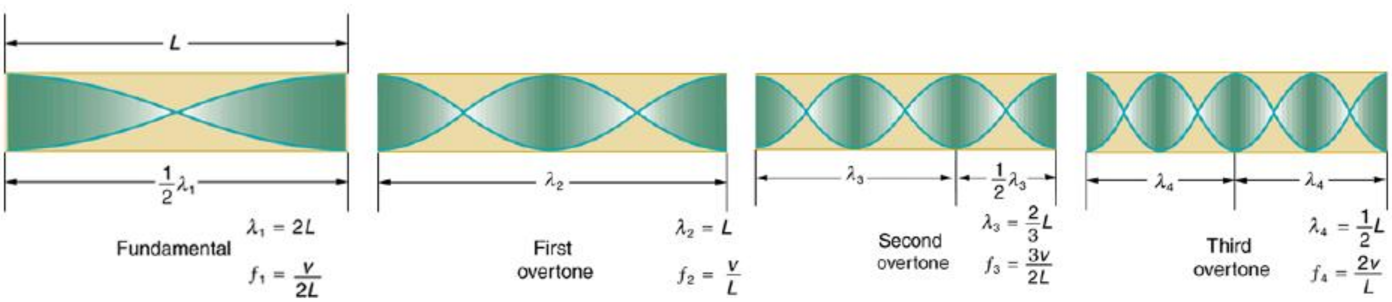
6. Draw the fundamental for a pipe that is closed at both ends. How much of a wavelength does the pipe length represent?

Practice – 16.10 & 17.5 Superposition, Interference and Resonance

1. A "showy" custom-built car has two brass horns that are supposed to produce the same frequency but actually emit 263.8 and 264.5 Hz. What beat frequency is produced?

2. A piano tuner hears a beat every 2.00 s when listening to a 264.0-Hz tuning fork and a single piano string. What are the two possible frequencies of the string?

3. Another type of tube is one that is <u>open at both ends</u>. Examples are some organ pipes, flutes, and oboes. The resonances of tubes open at both ends can be analyzed in a very similar fashion to those for tubes closed at one end. The air columns in tubes open at both ends have maximum air displacements at both ends. A standing wave occurs at resonance.



A. What is the fundamental frequency of a 0.672-m-long tube, open at both ends, on a day when the speed of sound is 344 m/s?

B. What is the frequency of its second harmonic?

4. How long must a flute be in order to have a fundamental frequency of 262 Hz (this frequency corresponds to middle C on the evenly tempered chromatic scale) on a day when air temperature is 20.0°C? It is open at both ends.

5. A. Find the length of an organ pipe closed at one end that produces a fundamental frequency of 256 Hz when air temperature is 18.0°C.

   B. What is its fundamental frequency at 25.0°C?

6. Students in a physics lab are asked to find the length of an air column in a tube closed at one end that has a fundamental frequency of 256 Hz. They hold the tube vertically and fill it with water to the top, then lower the water while a 256-Hz tuning fork is rung and listen for the first resonance.
   A. What is the air temperature if this first resonance occurs for a length of 0.336 m?

   B. At what length will they observe the second resonance (first overtone)?

<u>Answers</u>:

1. 0.7 Hz	2. 263.5 Hz, 264.5 Hz	3. A. 256 Hz	B. 512 Hz	4. 0.655 m
5. A. 0.334 m	B. 259 Hz	6. A. 21.5 °C	B. 1.01 m	

Resonance Lab

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

Setup:

1 ruler	1 meter stick	$v = 331.3\sqrt{1+\frac{T}{273.15}}$ m/s
1 large graduated cylinder	1 thermometer	
1 white PVC pipe	1 512 Hz tuning fork	$v = f\lambda$

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 your 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 % error = 100% $\times \frac{(\exp - \text{act})}{\text{act}}$. 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% $\times \frac{(\text{observed} - actual)}{actual}$			

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?

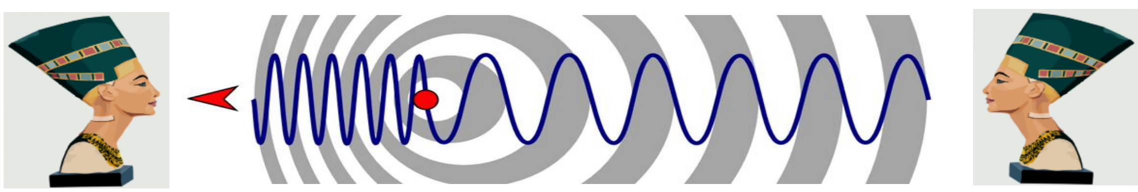
6. As you pull the pipe from the water, you first hear the first harmonic. Next you hear the 3rd harmonic. Why did you not hear a 2nd harmonic? You can use a drawing to explain.

Notes – 17.4 Doppler Effect

1. The Doppler effect (or Doppler shift) is named after the Austrian physicist Christian Doppler who proposed it in 1842. It is the change in frequency of a wave for an observer moving relative to the source of the wave. It is commonly heard when a vehicle sounding a siren or horn approaches, passes, and recedes from an observer.

2. The sound that is heard shifts from a ________________ frequency to a ________________ frequency.

3. This effect is due to motion of either the ________________ or the ________________.



4. Illustrate sound waves emanating from a slower and a faster object, both of which are producing sound waves of the same frequency and amplitude. Label the slow and fast objects, and indicate where observers would hear the higher and lower frequencies associated with the Doppler Effect.

5. Describe the conditions under which a moving object can cause a "sonic boom." Draw a diagram of the moving object and the sound waves that it is producing, and show where a sonic boom would be experienced by an observer.