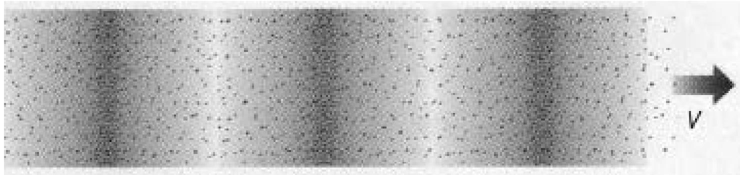
Physics 221, April 19

Key Concepts:

- Traveling sound waves
- Standing sound waves
- The Doppler effect

Traveling sound waves



For a traveling sound wave in we have for the pressure variations

$$\Delta P(x,t) = \Delta P_{max}\sin(kx - \omega t + \phi).$$

The corresponding displacements from the equilibrium position are

$$\Delta s(x,t) = \Delta s_{max}\cos(kx - \omega t + \phi).$$

The speed of sound in air at standard temperature and pressure is 343 m/s, independent of the frequency or wavelength.

The energy carried by a sound wave is proportional to the square of its amplitude.

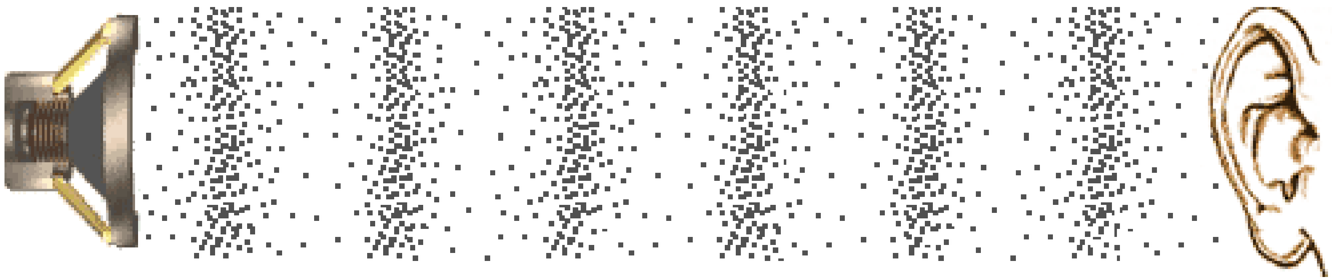
Sound levels β are measured using a logarithmic scale.

$$\beta = 10 \log_{10}(I/I_0)$$

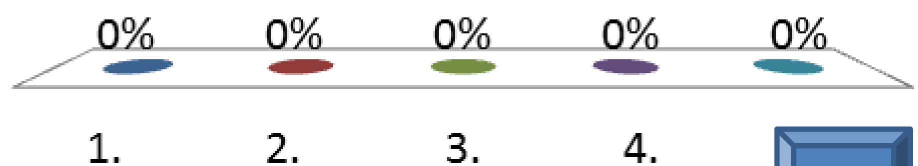
The units of β are decibels (dB). $I_0 = 10^{-12}$ W/m^2 is the reference intensity.

MULTIPLY the intensity by 10 < = > ADD another 10 dB to the sound level

Which sounds travel the fastest through air?



1. higher pitch sound
2. lower pitch sound
3. louder sound
4. quieter sound
5. All sound travels at the same speed through air.



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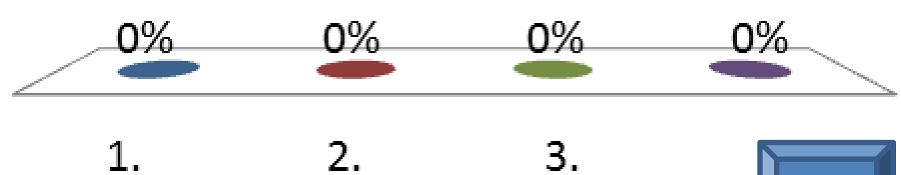
A pure sound notes from a sources make the molecules of air at a location vibrate with simple harmonic motion in accordance with the equation
$y_1 = 0.008 \sin(604\pi t)$.
What is the frequency of the sound wave?

What is ω?
What is f?

1. 604 Hz
2. 302 Hz
3. 96 Hz
4. 1898 Hz



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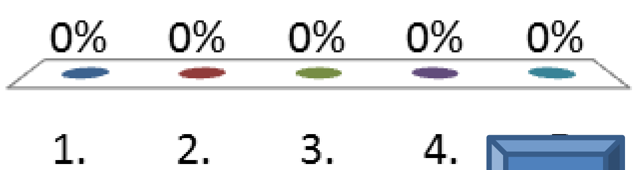
If the intensity of a 40 dB sound is increased to 80 dB, the intensity in W/m^2 increases by a factor of

Hint:
MULTIPLY the intensity by 10 < = >
ADD another 10 dB to the sound level

1. 2.
2. 4.
3. 40.
4. 10^4.
5. 10^{40}.

Sound level examples:

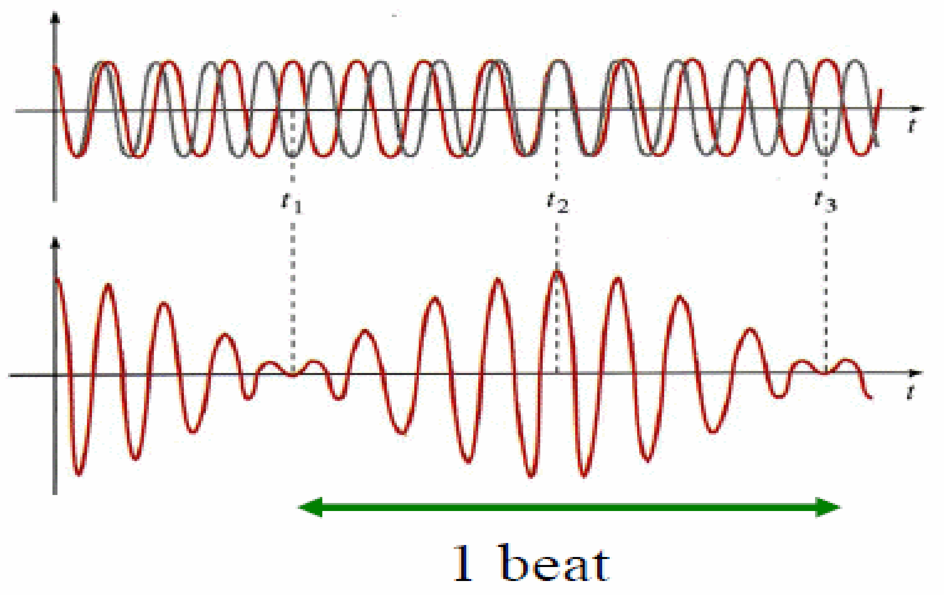
10 dB: Rustling or falling leaves
50 dB: Conversation.
100 dB: Hearing damage after about 15 minutes.



Beats

Intensity modulations are produced when waves of slightly different frequencies are superimposed.

The beat frequency is equal to the difference frequency $|f_1 - f_2|$.



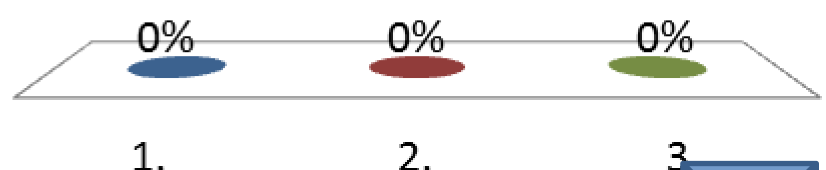
Demonstration:

A speaker box containing two oscillators, one fixed and the other variable.

By tuning the variable oscillator we can produce audio beats.

Two flutists are tuning up. If the conductor hears the beat frequency increasing, are the two flute frequencies getting closer together or father apart?

1. Closer
2. Farther apart
3. No way to tell



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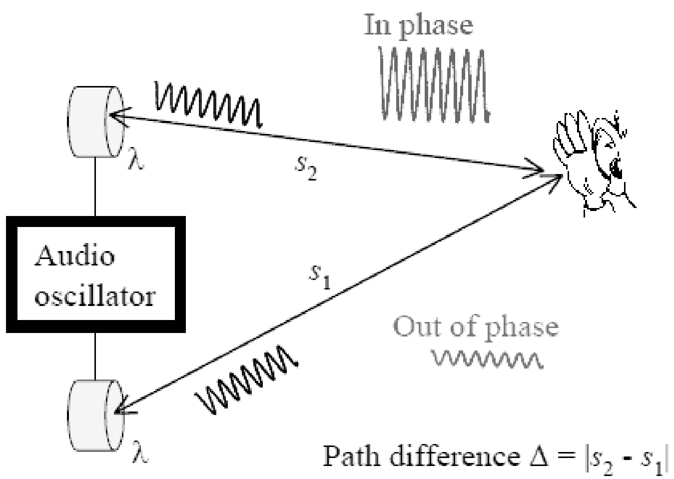
Interference

Demonstration: Two speakers and a sine wave generator. The speakers are driven by the same signal and can move in or 180 degrees out of phase.

Like all waves, two or more sound waves traveling trough the same medium will interfere. We can have constructive and destructive interference.

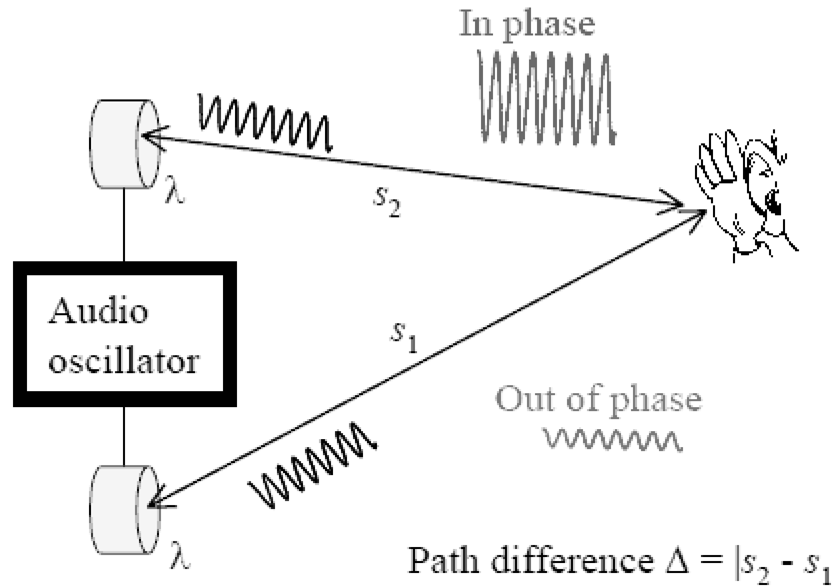


Assume s_1 = 5 m and s_2 = 4 m. The path difference Δ = 1 m. If $\Delta = m*\lambda$ with m = integer, then we have constructive interference.

Constructive interference: $\lambda = \Delta/m$, $f = v/\lambda = mv/\Delta$.
Destructive interference: $\lambda = \Delta/(m + ½)$, $f = v/\lambda = (m + ½)v/\Delta$.

If Δ = 1 m and the speed of sound is 340 m/s, which statement is correct?

1. At the frequency f = 680 Hz the sound at the position of the listener is loud.
2. At the frequency f = 1190 Hz the sound at the position of the listener is very soft.
3. At the frequency f = 340 Hz the sound at the position of the listener is loud.
4. All of the above statements are correct.



Hint: Interference
constructive: $f = mv/\Delta$, $f*\Delta/v = m$
destructive: $f = (m + ½)v/\Delta$, $f*\Delta/v = m + ½$

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Constructive interference: $f = mv/\Delta$, $f*\Delta/v = m$

Destructive interference: $f = (m + ½)v/\Delta$, $f*\Delta/v = m + ½$

Here $\Delta = 1$ m.

If $f*\Delta/v$ is an integer, we have constructive interference,

if it is an integer plus ½, we have destructive interference.

Case 1: $f = 680$ Hz, $f*\Delta/v = 680/340 = 2$.

Case 2: $f = 1190$ Hz, $f*\Delta/v = 1190/340 = 3.5$.

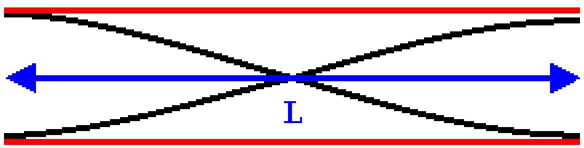
Case 3: $f = 340$ Hz, $f*\Delta/v = 340/340 = 1$.

Standing sound waves

We can create a standing wave in a tube, which is open on both ends, and in a tube, which is open on one end and closed on the other end. **Open and closed ends** reflect waves differently. Displacement variations are plotted.

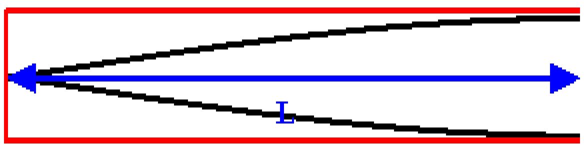
Fundamental

$\lambda = 2L \quad f = v / 2L$



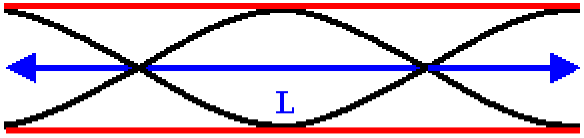
Fundamental

$\lambda = 4L \quad f = v / 4L$



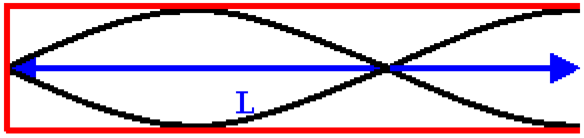
Second harmonic

$\lambda = L \quad f = v / L$



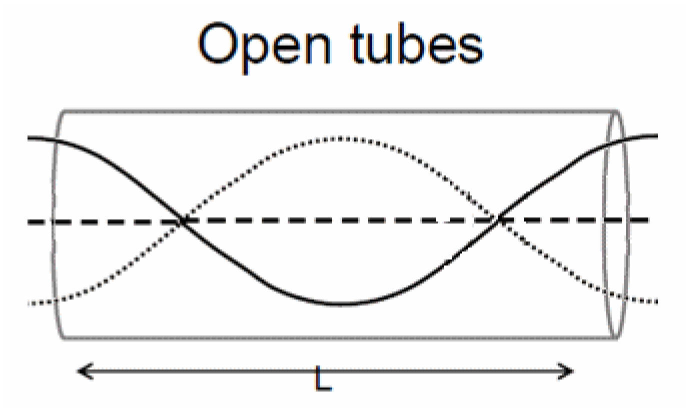
Third harmonic

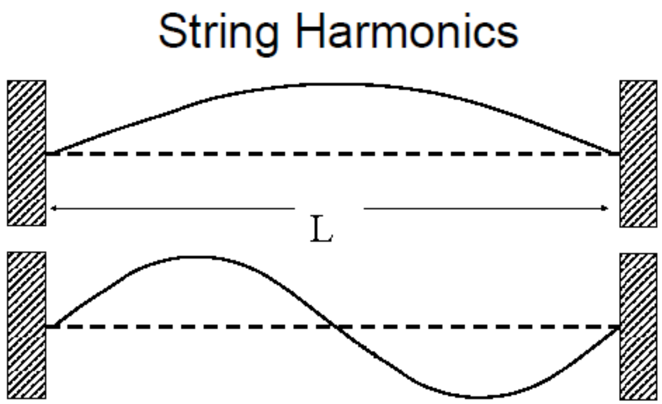
$\lambda = 4/3\,L \quad f = 3v / 4L$



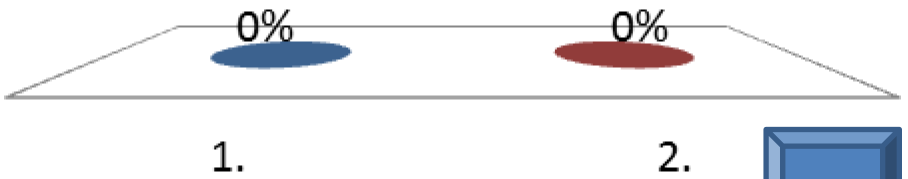
Demonstration: Singing Tubes

How will the wavelengths of the harmonics of an open tube compare with those of a string of the same length L?





1. They will be totally different.
2. They will be the same.



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While the wavelengths of the standing waves on the string and in the tube are the same, the speed of the sound waves is different from the speed of waves on a string.

$f = v/\lambda$

The frequencies will be different.

Doppler effect

The perceived pitch of a sound wave changes if the observer or the source is moving.

If both source and observer are in motion, then the apparent frequency of the sound wave reaching the observer is

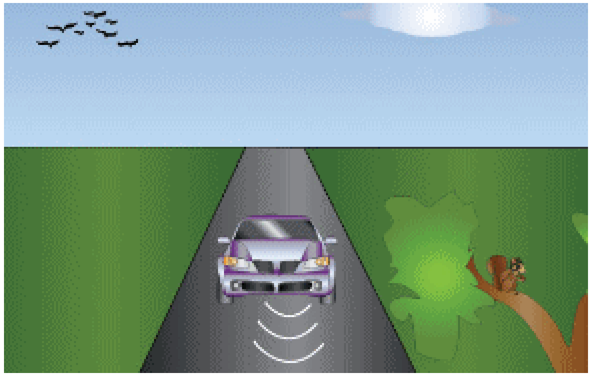
$f = f_0(v - v_{obs})/(v – v_s)$

v = velocity of sound

v_o = velocity component of the observer in the direction of v

v_s = velocity component of the source in the direction of v

When a car is at rest, its horn emits a sound wave of wavelength 0.55 m. A person standing in the middle of the street hears the horn with a frequency of 560 Hz. If the speed of sound is 330 m/s, should the person jump out of the way?



1. Yes
2. No

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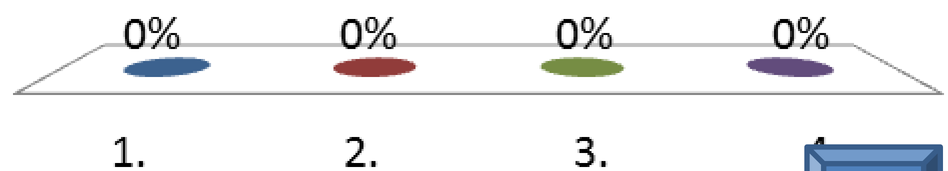
A train whistle is blown by the driver who hears the sound at 600 Hz. If the train is heading towards a station at 25.0 m/s, what will the whistle sound like to a waiting commuter? Take the speed of sound to be 340 m/s.

1. 600 Hz
2. 644 Hz
3. 625 Hz
4. 647 Hz



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