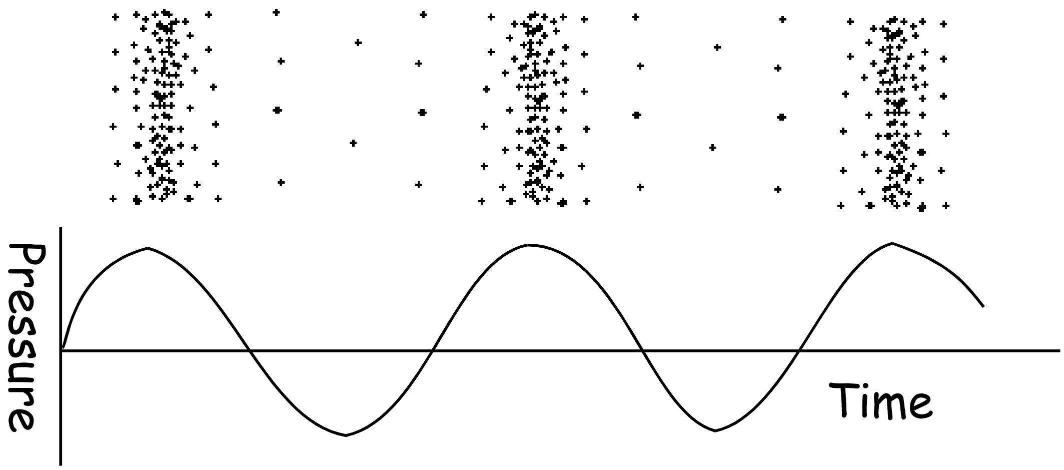
AP Physics – Sound LP

Attenu atio
n

Audibl e
Spectru m



The Doppler Effect

listener moving towards sound source

$$v = f\lambda \qquad so \qquad f = \frac{v}{\lambda} \qquad and \qquad \lambda = \frac{v}{f}$$

$$f' = \frac{v'}{\lambda} = \frac{v + v_0}{\lambda}$$

but $$\lambda = \frac{v}{f}$$

plug that into the equation

$$f' = \frac{v + v_0}{\lambda} = \frac{v + v_0}{\left(\frac{v}{f}\right)} = f\left(\frac{v + v_0}{v}\right)$$

new frequency heard by moving listener is:

$$f' = f\left(\frac{v + v_0}{v}\right)$$

listener moving away from sound source

$$f' = f\left(\frac{v - v_0}{v}\right)$$

Sound source moving - listener stationary:

λ' (wavelength collected by listener) shorter than ***λ***

During ***T***, the sound source moves a distance of;

$$v = \frac{x}{t} \qquad x = v_s t \qquad = v_s T \quad and \qquad T = \frac{1}{f}$$

$$x = v_s T \qquad = v_s\left(\frac{1}{f}\right) \qquad x = \frac{v_s}{f} \qquad \Delta\lambda = \frac{v_s}{f}$$

distance ***is*** change in wavelength:

Wavelength listener measures is:

$$\lambda' = \lambda - \Delta\lambda \qquad \lambda' = \lambda - \frac{v_s}{f} \qquad and \qquad \lambda = \frac{v}{f}$$

$$\lambda' = \lambda - \frac{v_s}{f} \quad so \quad \lambda' = \frac{v}{f} - \frac{v_s}{f} \qquad \frac{v}{f'} = \frac{v}{f} - \frac{v_s}{f}$$

solve for f'*:*

$$v = \left(\frac{v}{f} - \frac{v_s}{f}\right)f' \qquad vf = \left(v - v_s\right)f' \qquad \left(\frac{v}{\left(v - v_s\right)}\right)f = f'$$

So, cleaning it up a bit, we get:

$$f' = f\left(\frac{v}{v - v_s}\right) \qquad and \qquad f' = f\left(\frac{v}{v + v_s}\right)$$

When solving Doppler problems, we will assume that the speed of sound is 345 m/s.

- A train is traveling at 125 km/h. It has a 550.0 Hz train whistle. What is frequency heard by a stationary listener in front of train?

First, convert the train's speed to meters per second:

$$125\frac{\not{km}}{\not{h}}\left(\frac{1\ \not{h}}{3\,600\ s}\right)\left(\frac{1\,000\ m}{1\ \not{km}}\right) = 34.72\frac{m}{s}$$

Then plug the data into the equation which you will have derived (as above). Make sure to use the proper sign. In this case the train is closing on the listener, so the negative sign is selected.

$$f' = f\left(\frac{v}{v \pm v_s}\right) = 550.0\ Hz\left(\frac{345\frac{\not{m}}{\not{s}}}{345\frac{\not{m}}{\not{s}} - 34.72\frac{\not{m}}{\not{s}}}\right) = \boxed{612\ Hz}$$

Supersonic travel

shock wave or ***sonic boom***.

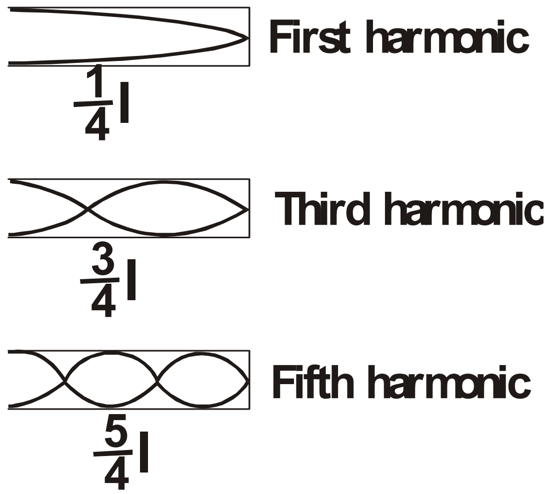
Resonance

Natural Frequency

Forced Vibrations

Resonant Air Columns

Close Ended Pipes:



open end of the pipe is, for all practical purposes, a displacement antinode and a pressure node.

The reflected wave pulse from an open end of the pipe is reflected in phase

open end of a pipe is essentially the atmosphere, so no pressure variations take place.

Only the odd harmonics are present in a resonating close-ended pipe.

The equation that relates wavelength, frequency and wave speed is:

$$v = f\lambda$$

For the fundamental frequency (the first harmonic), the wavelength is:

$$\lambda = 4l$$

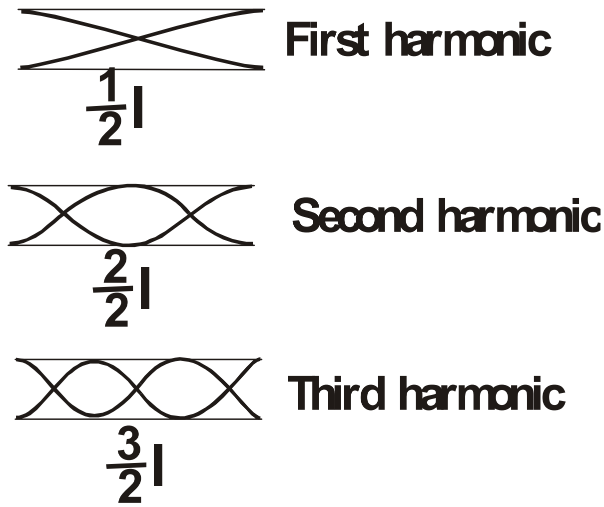
The frequency in the system must be:

$$v = f\lambda \quad = f(4l) \qquad f = \frac{v}{4l}$$

If we want the frequency of the third or fifth or whatever harmonic, we would get:

$$f_n = n\frac{v}{4L} \qquad n = 1, 3, 5, \ldots$$

Open Ended Pipes:



open ended pipe has all harmonics present.

$$f_n = n\frac{v}{2L} \qquad n = 1, 2, 3, \ldots$$

A critical difference between the open and close-ended pipes is that the open-ended pipe can have all harmonics present. The close-ended pipe is limited to the odd harmonics.

All harmonics can be present in a resonant open-ended pipe.

- A pipe is closed at one end and is 1.50 m in length. If the sound speed is 345 m/s, what are the frequencies of the first three harmonics that would be produced?

Use the close ended pipe formula to find the first harmonic (the fundamental frequency):

$$f_n = n\frac{v}{4L} \qquad f_1 = \frac{v}{4L}$$

$$f_1 = 345\frac{m}{s}\left(\frac{1}{4\left[1.50\ m\right]}\right) = \boxed{57.5\ Hz}$$

Recall that close ended pipes only have the odd harmonics, so the next two would be the third and fifth harmonics:

$$f_3 = n\left(f_1\right) = 3\left(57.5\ Hz\right) = 172\ Hz$$

$$f_5 = n\left(f_1\right) = 5\left(57.5\ Hz\right) = 288\ Hz$$