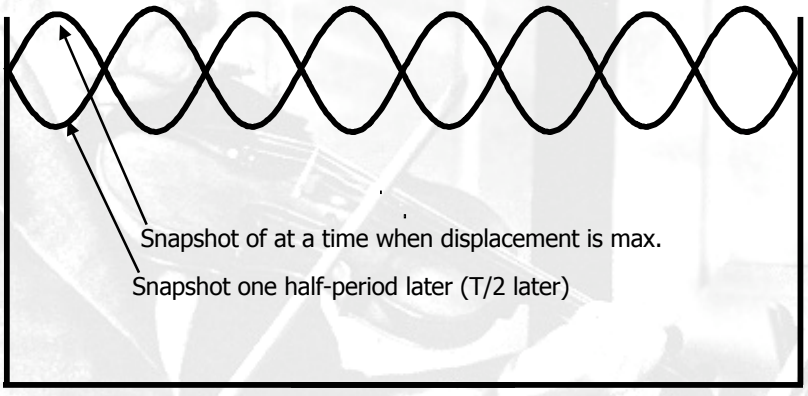
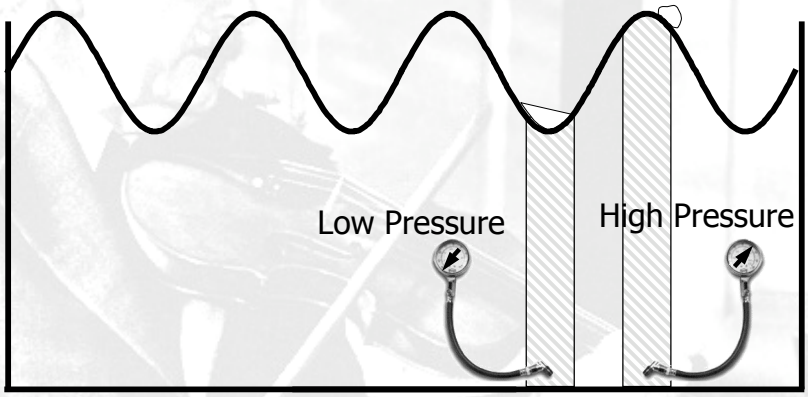
Week 5

Standing waves in Air Columns

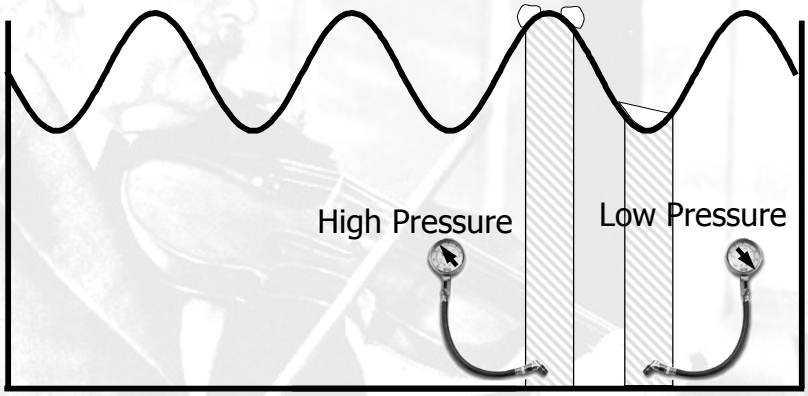
Standing Waves in the Bathtub



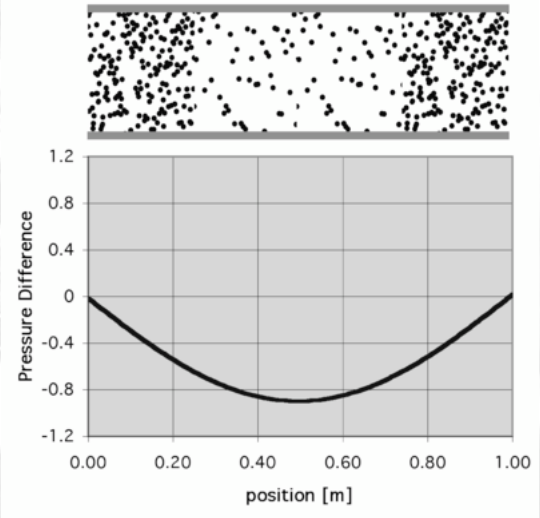
Standing Waves in the Bathtub



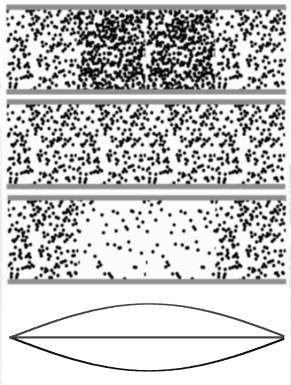
Standing Waves in the Bathtub



Both Ends Open: 1. Mode



Both Ends Open: 1. Mode



phase

$0 \;\&\; T$

$\frac{1}{4}T \;\&\; \frac{3}{4}T$

$\frac{1}{2}T$

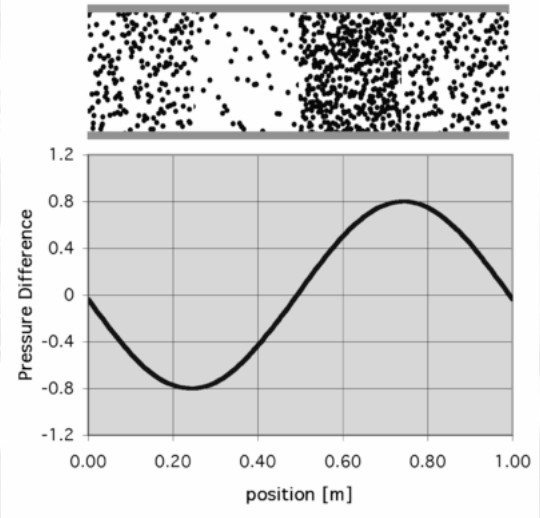
wavelength

$\lambda_1 = 2L$

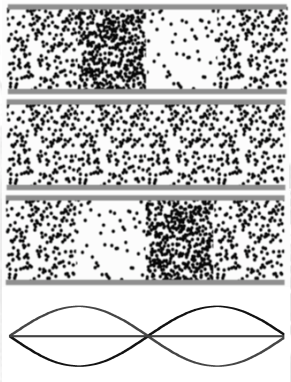
frequency

$f_1 = \frac{v}{2L}$

Both Ends Open: 2. Mode



Both Ends Open: 2. Mode



phase

$0 \;\&\; T$

$\frac{1}{4}T \;\&\; \frac{3}{4}T$

$\frac{1}{2}T$

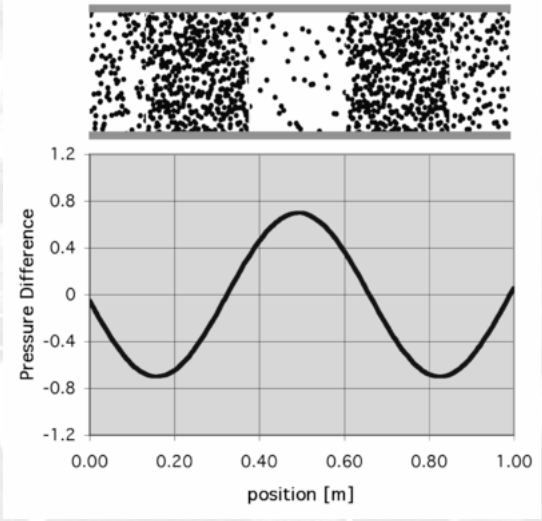
wavelength

$$\lambda_2 = L = \frac{1}{2}2L$$

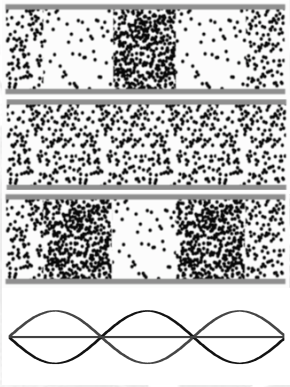
frequency

$$f_2 = 2\frac{v}{2L} = 2f_1$$

Both Ends Open: 3. Mode



Both Ends Open: 3. Mode



phase

$0 \;\&\; T$

$\frac{1}{4}T \;\&\; \frac{3}{4}T$

$\frac{1}{2}T$

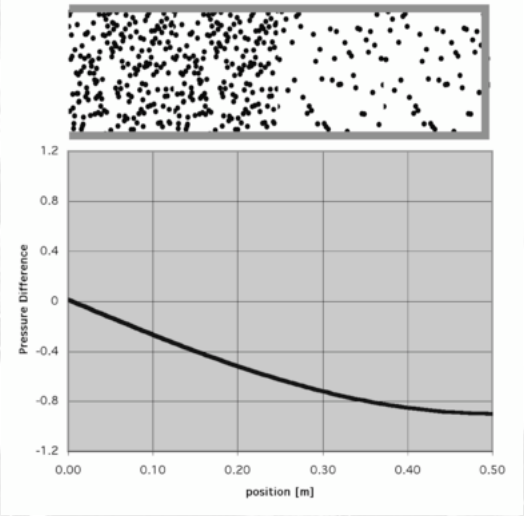
wavelength

$$\lambda_3 = \frac{1}{3}2L$$

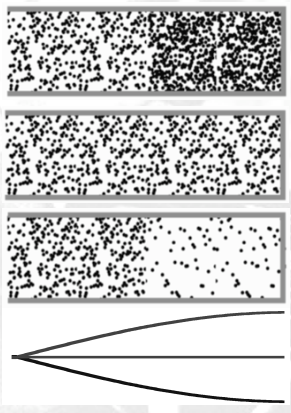
frequency

$$f_3 = 3\frac{v}{2L} = 3f_1$$

One End Closed: 1. Mode



One End Closed: 1. Mode



phase

$0 \;\&\; T$

$\frac{1}{4}T \;\&\; \frac{3}{4}T$

$\frac{1}{2}T$

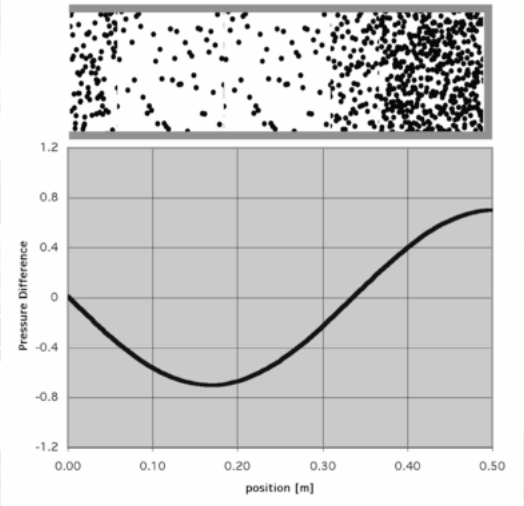
wavelength

$\lambda_1 = 4L$

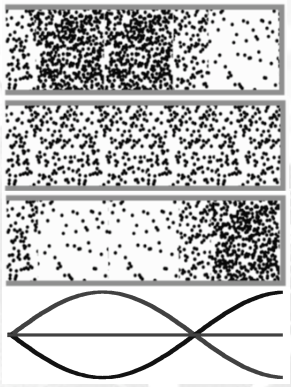
frequency

$f_1 = \frac{v}{4L}$

One End Closed: 2. Mode



One End Closed: 2. Mode



phase

$0 \;\&\; T$

$\frac{1}{4}T \;\&\; \frac{3}{4}T$

$\frac{1}{2}T$

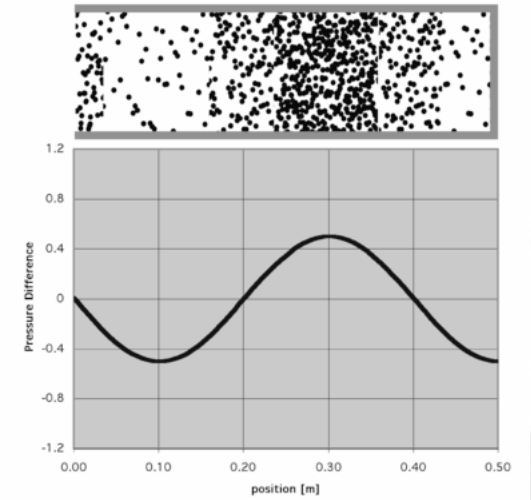
wavelength

$$\lambda_2 = \frac{4}{3}L$$

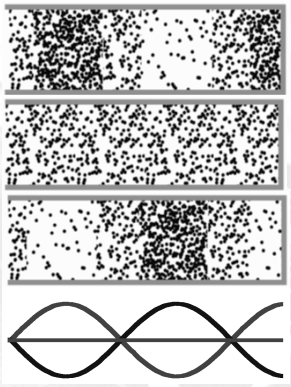
frequency

$$f_2 = 3\frac{v}{4L}$$

One End Closed: 3. Mode



One End Closed: 3. Mode



phase

$0 \;\&\; T$

$\frac{1}{4}T \;\&\; \frac{3}{4}T$

$\frac{1}{2}T$

wavelength

$$\lambda_3 = \frac{4}{5}L$$

frequency

$$f_3 = 5\frac{v}{4L}$$

Strings, Rods, and Air Columns

Strings (both ends fixed)	$\lambda_n = \frac{1}{n} 2L$	$f_n = n \frac{v}{2L}$	(n =1,2,3...)
Thin Rod (one end fixed)	$\lambda_n = \frac{1}{2n-1} 4L$	$f_n = (2n\text{-}1) \frac{v}{4L}$	(n=1,2,3...)
Air Column (both ends open)	$\lambda_n = \frac{1}{n} 2L$	$f_n = n \frac{v}{2L}$	(n =1,2,3...)
Air Column (one end closed)	$\lambda_n = \frac{1}{2n-1} 4L$	$f_n = (2n\text{-}1) \frac{v}{4L}$	(n=1,2,3...)

What do they have in common?

Loose string/rod and *closed* end of pipe
must have an antinode

Fixed string/rod and *open* end of pipe
must have an node

Strings, Rods, and Air Columns

Strings (both ends fixed)

$$\lambda = 2L,\ \frac{1}{2}2L,\ \frac{1}{3}2L,\ \frac{1}{4}2L...$$

Air Column (both ends open)

$$f = 1\frac{v}{2L},\ 2\frac{v}{2L},\ 3\frac{v}{2L},\ 4\frac{v}{2L}...$$

Rod (one end fixed)

$$\lambda = 4L,\ \frac{1}{3}4L,\ \frac{1}{5}4L,\ \frac{1}{7}4L...$$

Air Column (one end closed)

$$f = 1\frac{v}{4L},\ 3\frac{v}{4L},\ 5\frac{v}{4L},\ 7\frac{v}{4L}...$$

Some Consequences…

Short Blades – Long Blades

The shorter the blade, the higher the resonance frequency

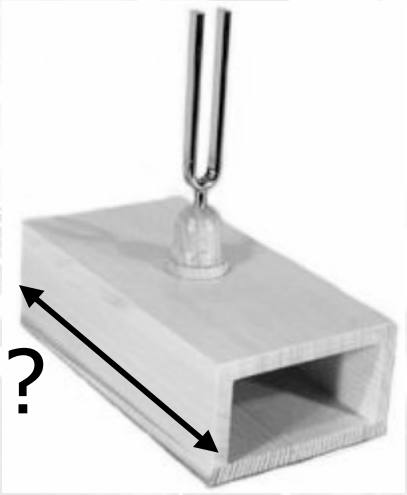
$$f_1 = \frac{v}{4L}$$

Clarinet *vs.* Flute Playoff

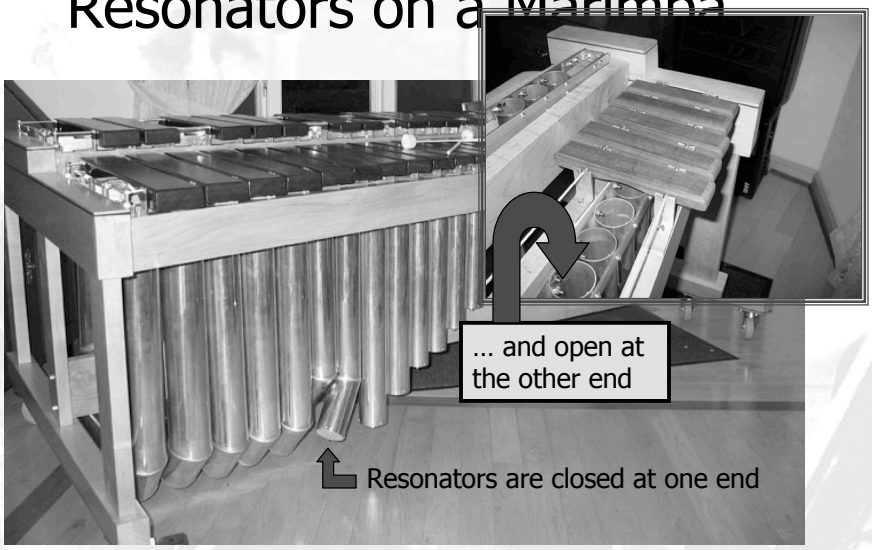
Same length (nearly) but clarinet is much lower

Tuning Fork Resonator

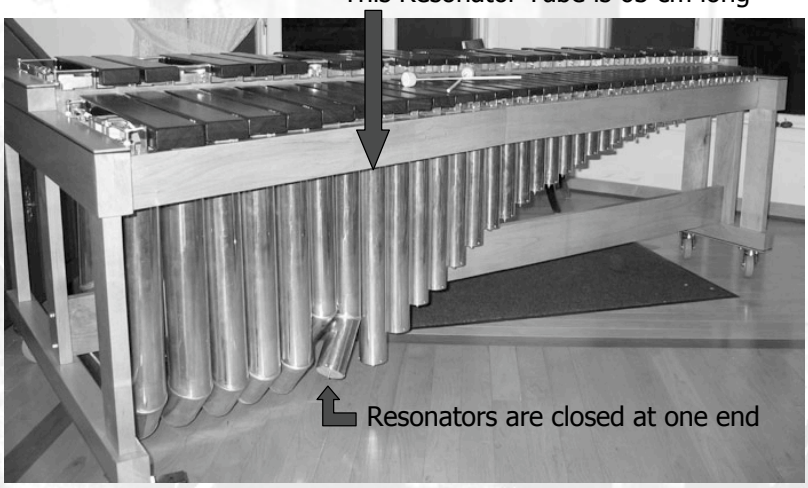
How Long?



Resonators on a Marimba



Resonators on a Marimba



Forcing the 3. Mode on a String