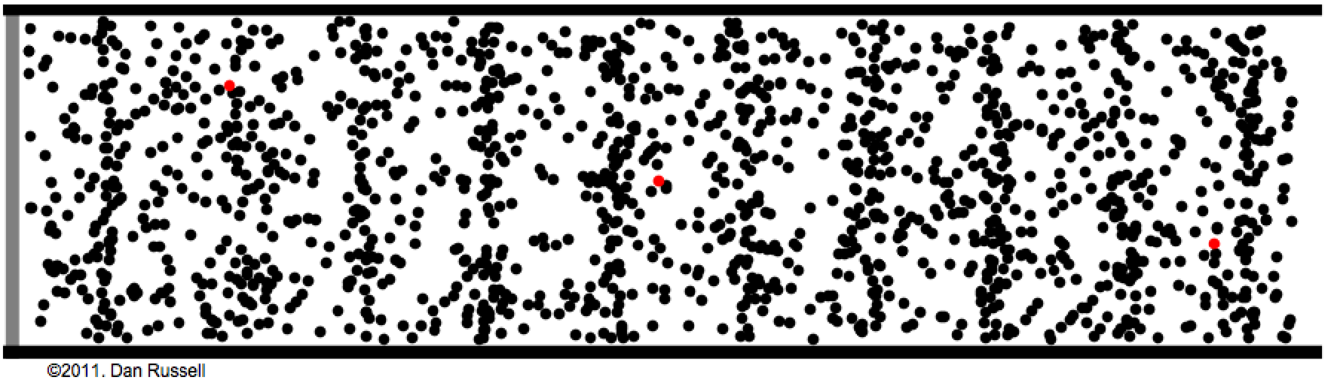
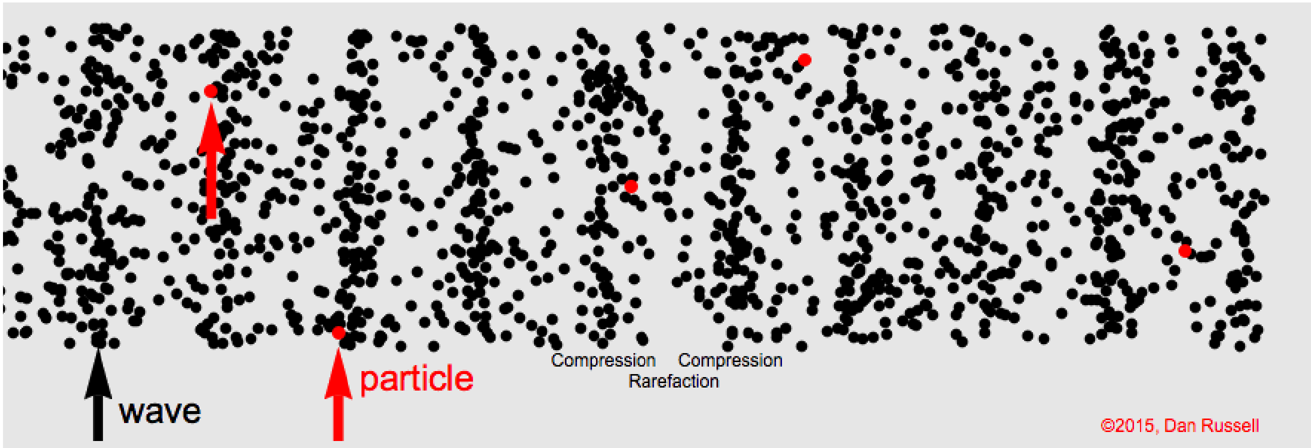
Sound Summary Notes

1. *What is sound?*
2. *Speed of Sound*
3. *Sound Intensity*
4. *Sound Pitch*
5. *Standing Waves in Air Columns*
6. *Doppler Effect*

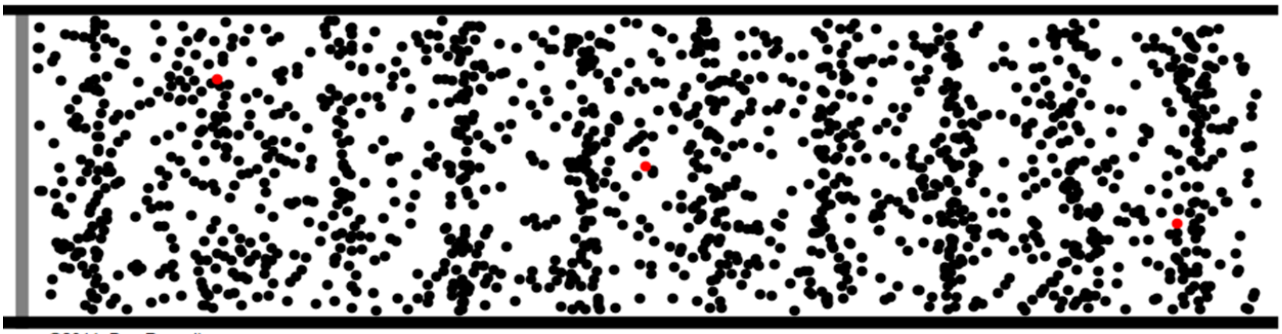
1. What is Sound

Sound is a longitudinal wave of air pressure variations, caused by a rapidly vibrating source (i.e. a tuning fork or your vocal cords)





1. What is Sound



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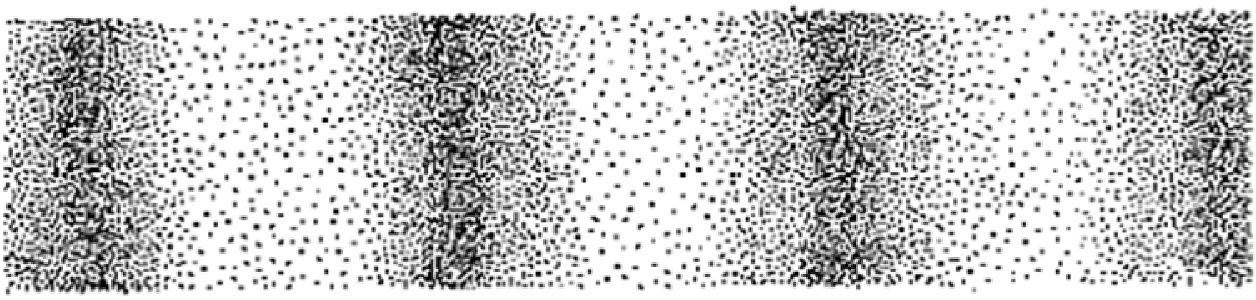
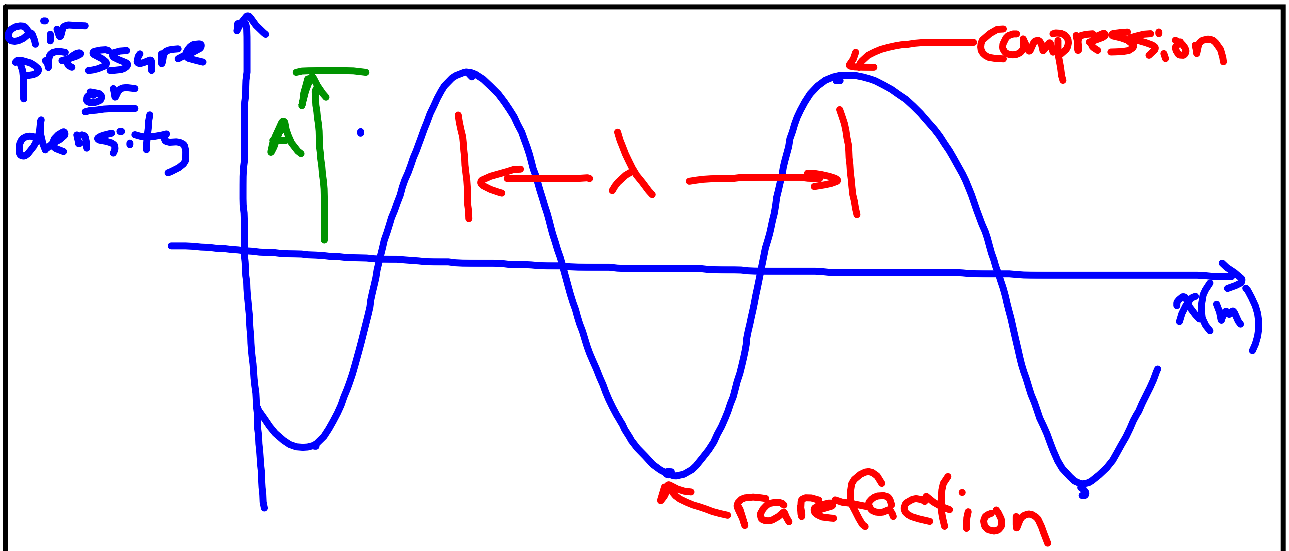




amplitude A → is a measure of air pressure.

2. Speed of sound

The speed of sound at sea level and 0°C is **332 m/s**. ~1200 km/hr

Factors affecting the speed of sound:

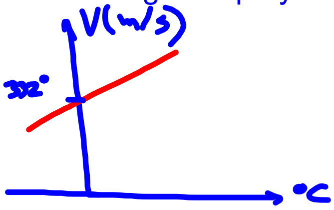
→ temperature as T↑, v↑

→ air pressure as P↑, v↑

→ properties of medium transmitting the wave

- humidity

As the temperature ↑ the air molecules are moving faster and sound waves can be transmitted faster. For each degree Celcius the velocity of sound goes up by 0.59m/s.



$$V = 332 + 0.59T$$

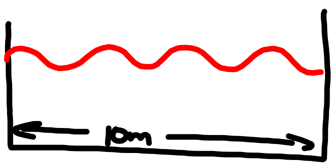
1. What is the speed of sound when the temperature is 25°C & -25°C?

-25°C $V = 332 + .59(-25) = 317$

+25°C $V = 332 + .59(25) = 347$

~30 m/s ~108 km/hr

2. The middle C note on a piano vibrates at 262 Hz. How many vibrations does it make when the sound travels across a room 10m wide at a temperature of 10°C?



$V = 332 + .59(10)$

$= 338\ m/s$

$f = 262\ Hz$

$\lambda = \frac{V}{f} = \frac{338\ m/s}{262\ Hz} = 1.29\ m$

$\#\ waves = \frac{10\ m}{1.29\ m} = 7.75\ waves$

Speed of sound in other materials

increasing velocity ↓

• Air	332 m/s
• Helium	970 m/s
• Water	1493 m/s
• Glass	5050 m/s
• Aluminum	5104 m/s

Mach Number

- Mach number is defined as:

- Mach Number = $\frac{\text{speed of object}}{\text{speed of sound}}$

Warm-Up (Mach # Review)

If you are travelling at 1,224 km/hr and the air temperature is 30°C, what is your MACH #?

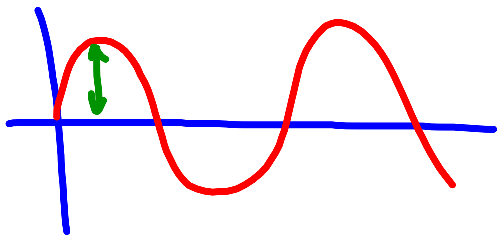
$$\text{Mach \#} = \frac{V_{object}}{V_{sound}} = \frac{340\text{ m/s}}{349.7\text{ m/s}}$$

$$= 0.97$$

$$V_{sound} = 332 + .59(30)$$
$$= 349.7\text{ m/s}$$

$$V_{object} = 1224\text{ km/hr} \div 3.6$$
$$= 340\text{ m/s}$$

3. Sound Intensity



Intensity is related to the amplitude of the wave.

Measure of the overall energy of the sound per unit area.

measured in W/m^2 W = Watt = J/s

Human Range is from about
$10^{-12} W/m^2$ to $1\ W/m^2$
0 dB 120 dB

A huge range (0.000000000001 to $1 W/m^2$)

Normally measured in dB (decibels).

Intensity Levels of Common Sources of Sound

Source	Intensity (dB)	Intensity (W/m^2)
threshold of hearing	0	10^{-12}
whisper	20 ↓ 100x's	10^{-10}
loud IPOD's	80-90	10^{-4} - 10^{-3}
loud rock concerts	120	$10^0 = 1$
threshold of pain	130	10^1
instant perforation of ear drum	160	10^4

increase in loudness from a change in dB.

x's increase = $10^{dB change/10}$

Practice

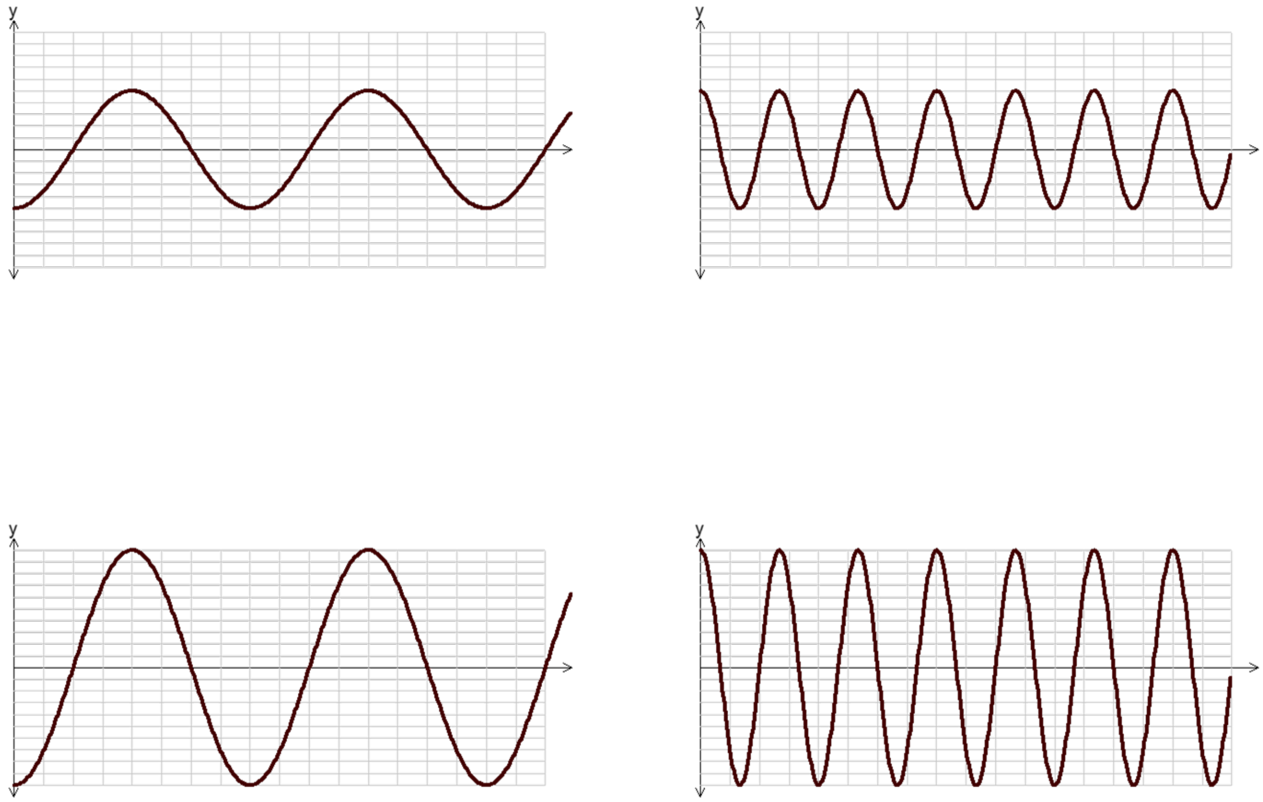
How many times louder is a 70dB sound compared to a 40 dB sound?

$\Delta dB = 30$

x's increase $10^{30/10}$

= 1000

4. Pitch and Sound Quality



- High pitch relates to short wavelengths and high frequency

- Sound Quality is a measure of the cleanliness of the signal

- What is white noise?

Just like white light, (white light is composed of all frequencies (wavelengths) of visible light), white noise is composed of all frequencies of audible sound.

4. Pitch and Sound Quality

Test – human response to frequency.

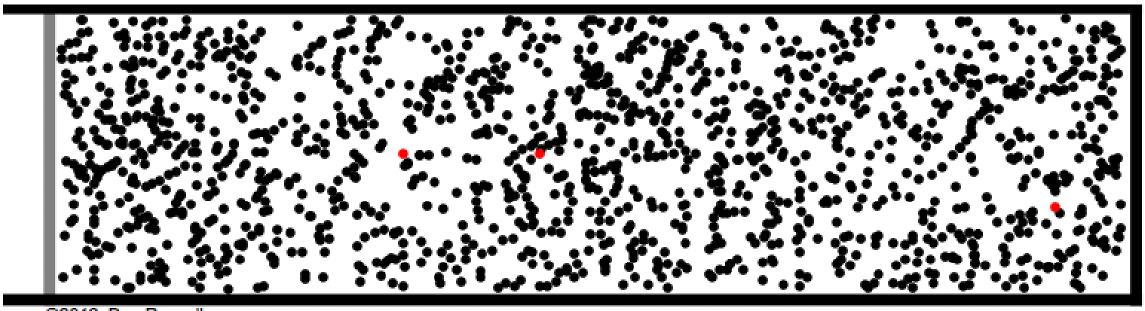
IPAD – TONE GENERATOR APPLICATION

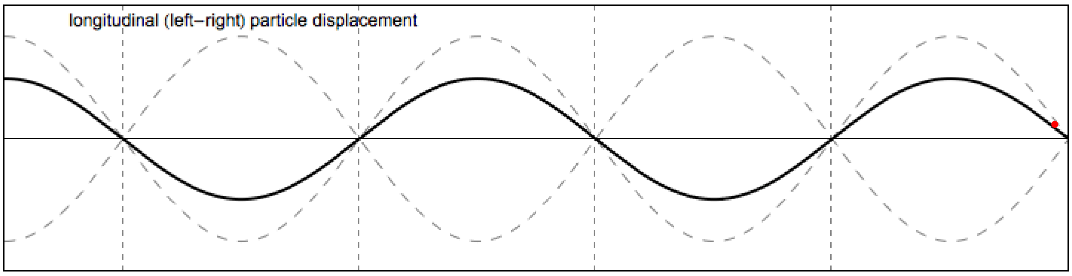
Normal Human Response
20Hz - 20kHz

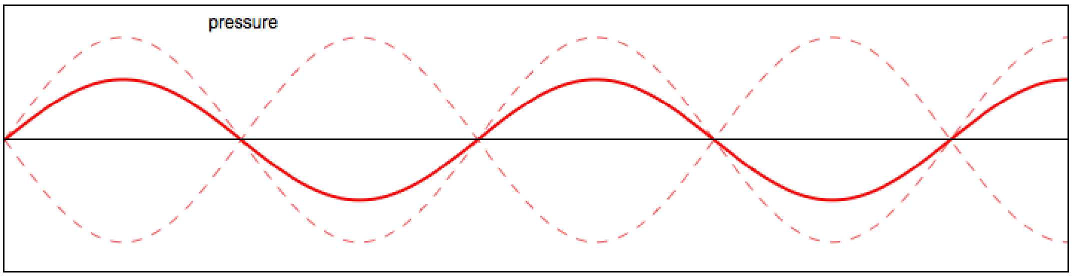
Ability to hear high frequencies drops off as we age ☹

http://newt.phys.unsw.edu.au/jw/flutes.v.clarinets.html#complications

5. Standing Waves in Air Columns



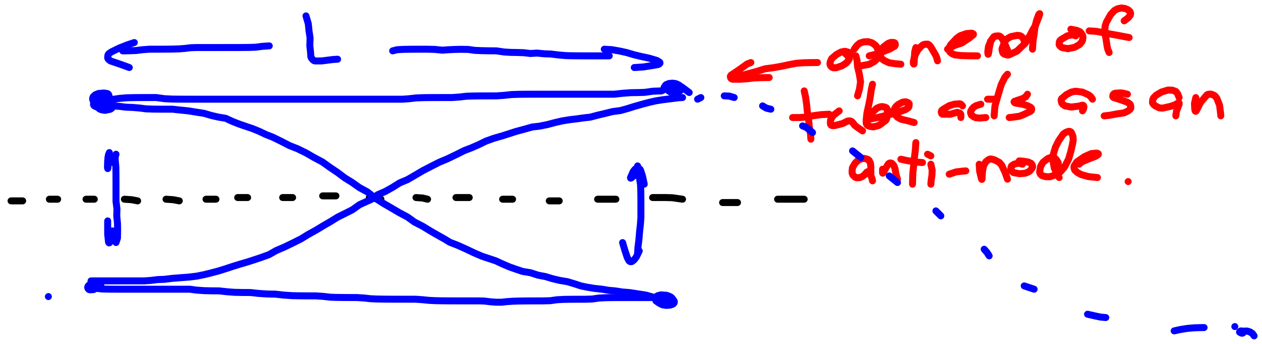




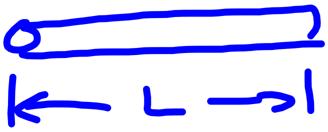
5. Standing Waves in Air Columns

Open Ended Columns (example - flute)

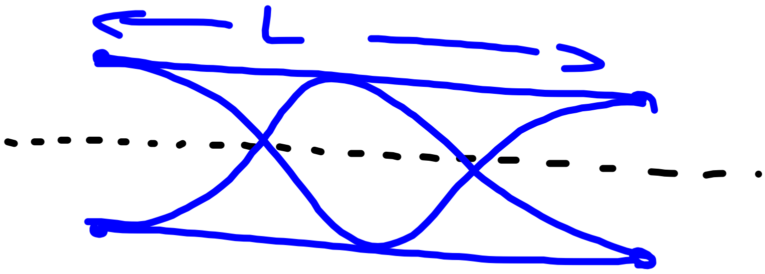
1ST Resonant Wavelength/Frequency



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

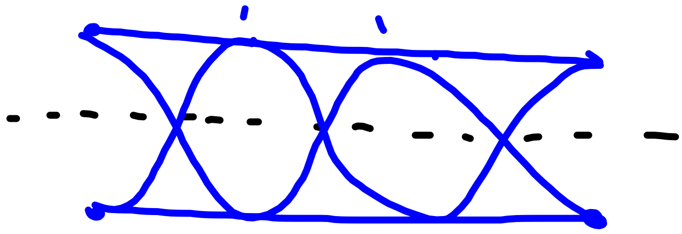


2ND Resonant λ



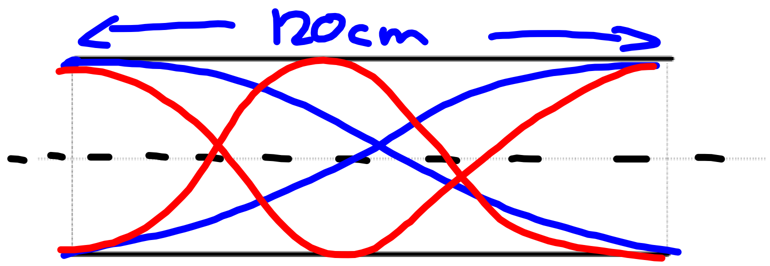
$L = 1\lambda$; $L = \frac{2}{2}\lambda$

3rd Resonant λ



$L = \frac{3}{2}\lambda$

1. An open air column is 120cm long. If the speed of sound is 344 m/s, calculate the frequency of a tuning fork that will cause the resonance at the first resonant length the second resonant length.



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

Open Ended Air Columns
examples : flute, recorder, trumpet

1st

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

$\lambda = 2L$

$= 2 \times 120cm$

$= 240cm$ or $2.4m$

$f = \frac{v}{\lambda} = \frac{344 m/s}{2.4m} = 143Hz$

2nd

$L = \frac{2}{2}\lambda$

$\lambda = L$

$= 120cm$ or $1.2m$

$f = \frac{v}{\lambda} = \frac{344 m/s}{1.2m} = 287Hz$

x2

3rd

$\lambda = 2.4m \div 3$

$= 0.8m$

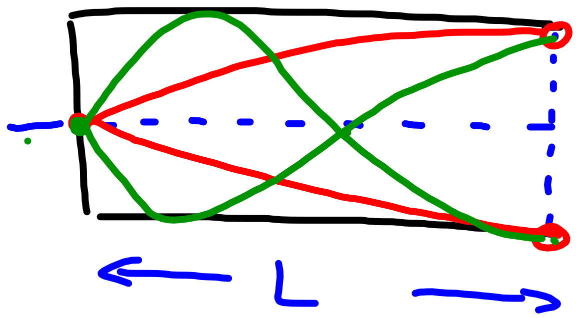
$f = 143 \times 3$

$= 430Hz$

x3

Standing Waves in Air Columns

Closed Ended Columns (1 end is closed, 1 end is open)



closed end acts as a node.

open end acts as an anti-node.

1 ST Resonant Wavelength ( )

$L = \frac{1}{4}\lambda_1$

2 ND Resonant Wavelength ( )

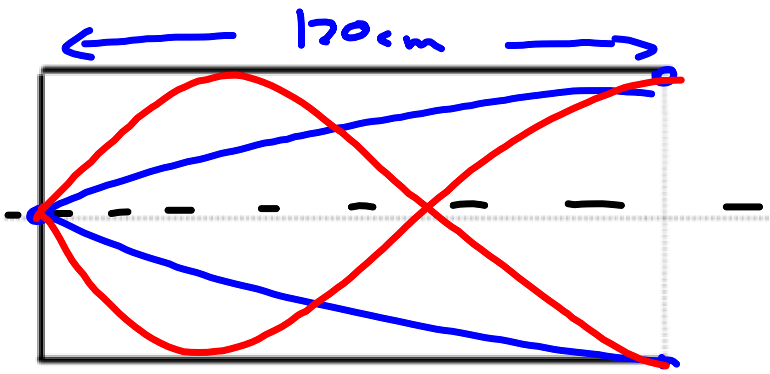
$L = \frac{3}{4}\lambda_2$

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

4 th $L = \frac{7}{4}\lambda_4$

2. A closed air column is 120cm long. If the speed of sound is 344 m/s, calculate the frequency of a tuning fork that will cause the resonance at the first resonant length and the second resonant length.

Closed Ended Air Columns
examples : clarinet, organ pipes



1ST

$L = \frac{1}{4}\lambda \Rightarrow \lambda = 4L$

$= 4 \times 120\,cm$

$= 480\,cm$ or $4.8\,m$

$f = \frac{v}{\lambda} = \frac{344\,m/s}{4.8\,m/s}$

$= 72\,Hz$

2ND

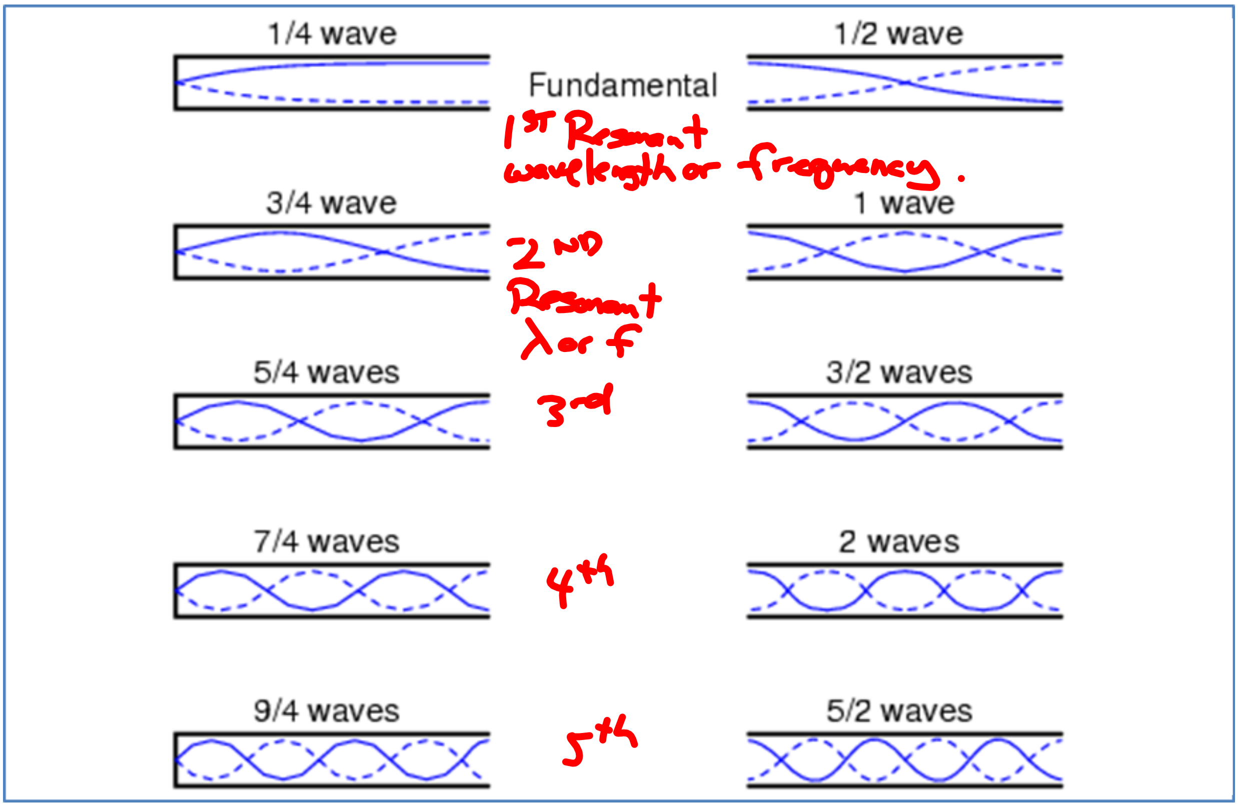
$L = \frac{3}{4}\lambda \Rightarrow \lambda = \frac{4}{3}L$

$= \frac{4}{3} \times 120\,cm$

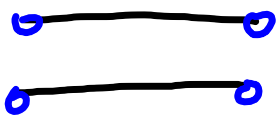
$= 160\,cm$ or $1.6\,m$

$f = \frac{v}{\lambda} = \frac{344\,m/s}{1.6\,m} = 215\,Hz$

Standing Waves in Air Columns



Summary : Standing Waves in Air Columns



Open Ended (both ends open)

$L = \frac{1}{2}\lambda_1$ *

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

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

⋮

$\lambda_1 = 2L$

$\lambda_2 = L$

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

Closed ended (1 end closed, 1 end open)

$L = \frac{1}{4}\lambda_1$ *

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

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

⋮

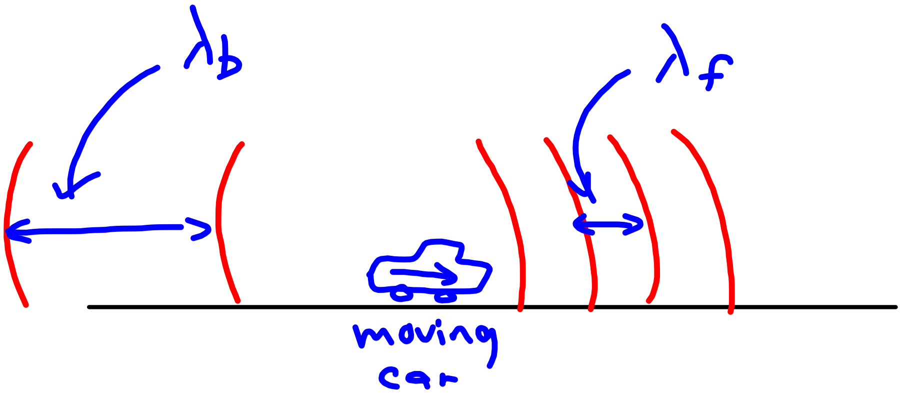
$\lambda_1 = 4L$

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

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

6. The Doppler Effect

λ - same everywhere



Back	Front
$\lambda_b > \lambda$	$\lambda_f < \lambda$
$\therefore f_b < f$	$\therefore f_f > f$
∴ pitch will decrease	∴ pitch will increase.