Exploring a Wave Model for Sound and Sound in Our World

Grade 11 Physics

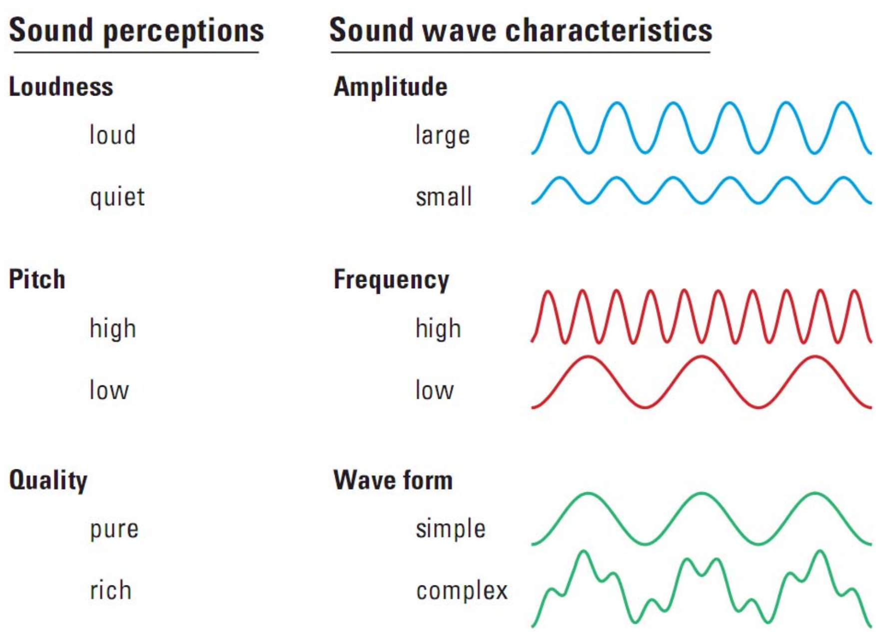
Sound = Wave ?
(Yes)

Wave = Sound?
(Not Really)

Important Factor of Sound

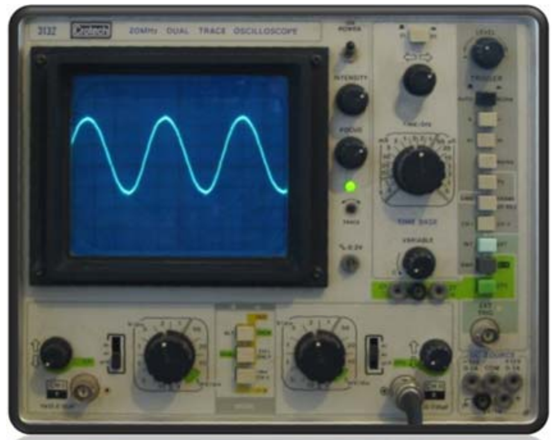
- Loudness (perceived Intensity)
  - Amplitude (dB – decibel)
- Pitch
  - Frequency (Hz – hertz)
- Quality
  - Complexity of the wave

Important Factor of Sound (Cont.)



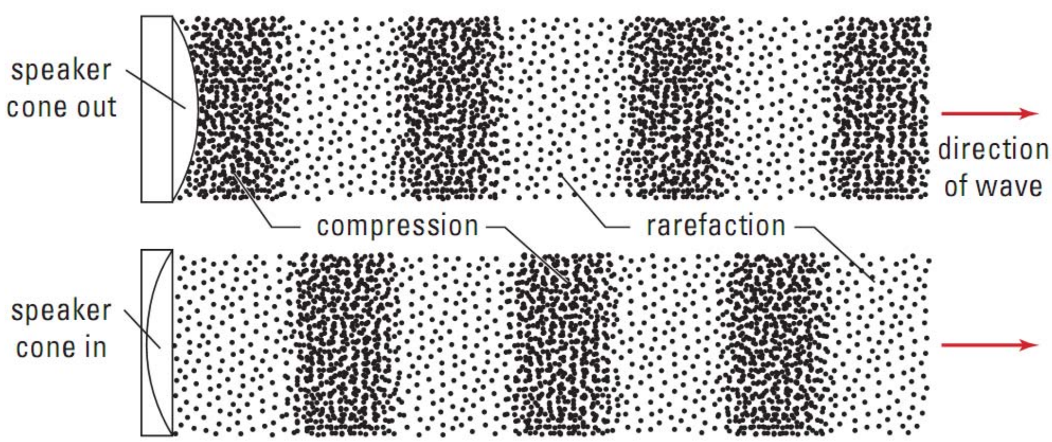
Seeing Waves

- Oscilloscope

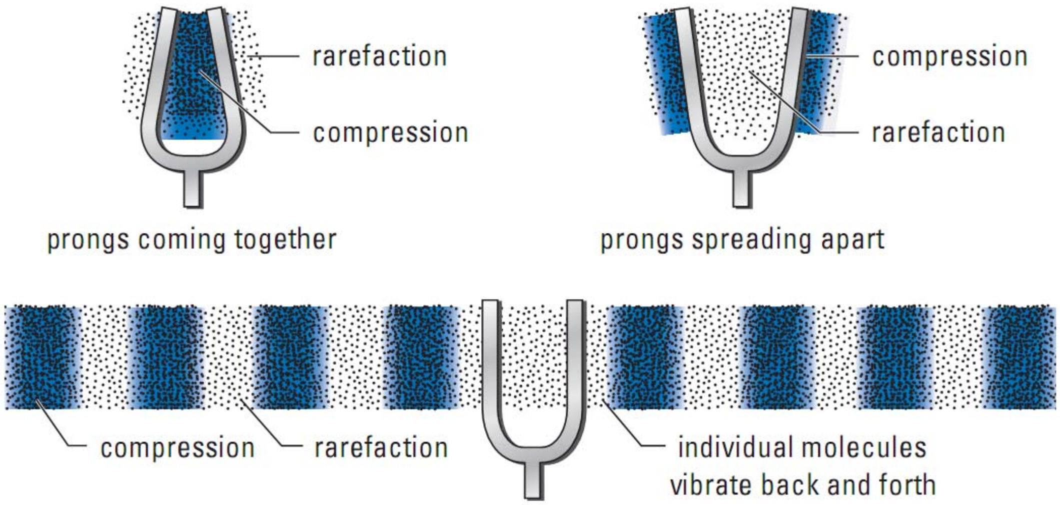


Transfer of Sound Wave

- Compression and Rarefaction
  - Longitudinal Wave (Sound)

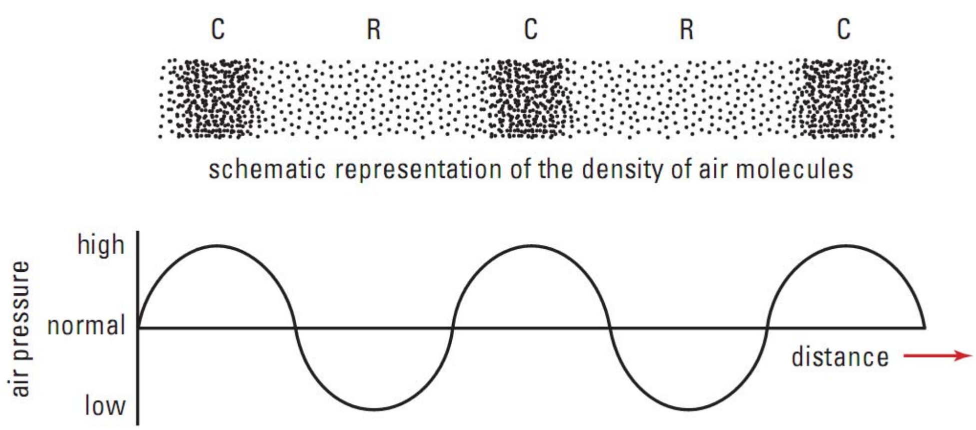


Transfer of Sound Wave (Cont.)



Transfer of Sound Wave (Cont.)

- Schematic Diagram VS Wave Graph



Speed of Sound in Air

- Speed of Sound in Air
  - The speed of sound in air is 331 plus the product of 0.59 and the Celsius temperature.

$$v = 331 + 0.59T_C$$

Quantity	Symbol	SI unit
speed of sound	v	$\frac{m}{s}$ (metres per second)
temperature of air	T_C	not applicable* (°C is not an SI unit)

Speed of Sound in Different Medium

- Speed of Sound in Different Medium

Material	Speed (m/s)
Gases (0°C and 101 kPa)	
carbon dioxide	259
oxygen	316
air	331
helium	965
Liquids (20°C)	
ethanol	1162
fresh water	1482
seawater (depends on depth and salinity)	1440–1500
Solids	
copper	5010
glass (heat-resistant)	5640
steel	5960

Example Problem

- EX1:
  - Suppose the room temperature of a classroom is 21^{o}C. Calculate the speed of sound in the classroom.

Example Problem

- EX2:
  - The temperature was 4.0^{o}C one morning as Martita hiked through a canyon. She shouted at the canyon wall and 2.8s later heard an echo. How far away was the canyon wall?

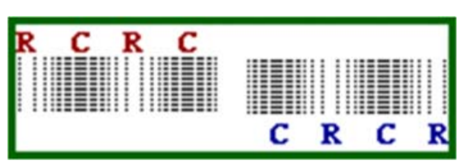
Interference of Sound Waves

Interference

- Destructive Interference
  - Amplitude is smaller than original

- Constructive Interference
  - Amplitude is higher than original

- Beat
  - Two similar frequencies but not the same frequencies
  - Act constructively and destructively



Beat Frequency

- Beat Frequency
  - The absolute value of the difference of the frequencies of the two component waves.

$$f_{\text{beat}} = |f_2 - f_1|$$

Quantity	Symbol	SI unit
beat frequency	f_{beat}	Hz (hertz)
frequency of one component wave	f_1	Hz (hertz)
frequency of other component wave	f_2	Hz (hertz)

Example Problem

- A tuning fork of unknown frequency is sounded at the same time as one of the frequency 440Hz, resulting in the production of beats. Over 15s, 46beats are produced. What are the possible frequencies of the unknown frequency of unknown tuning fork?

Vibrating Columns of Air

Music, Noise and Resonance in Air Columns

- Noise
  - Struck two stone together
  - No specific pitch
  - Just a sound but recognizable by us
  - Many sound frequencies with no recognizable relationship to each other
- Music
  - Harmonics of dominated frequencies
  - Whole-number multiples of the lowest frequency or fundamental frequency

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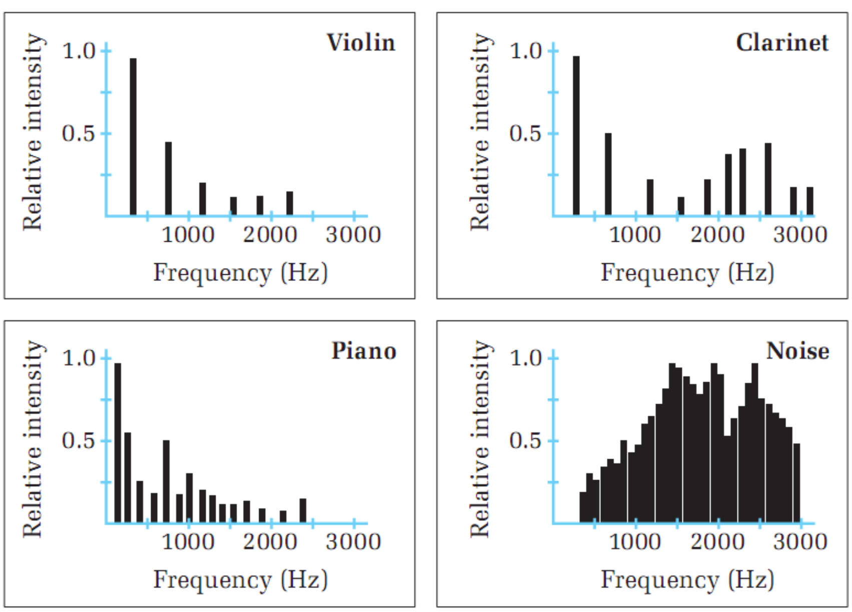
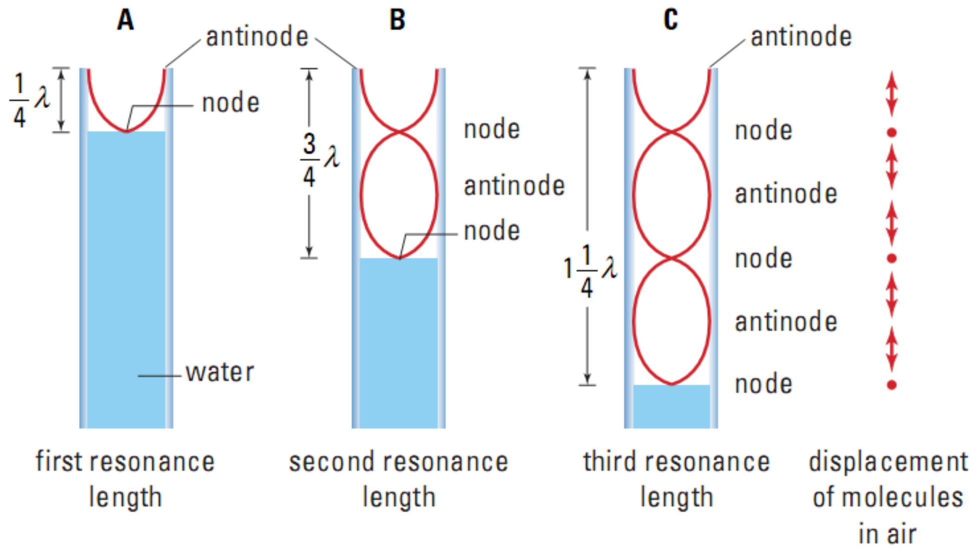
Music, Noise and Resonance in Air Columns



Resonance in a CLOSED Air Column

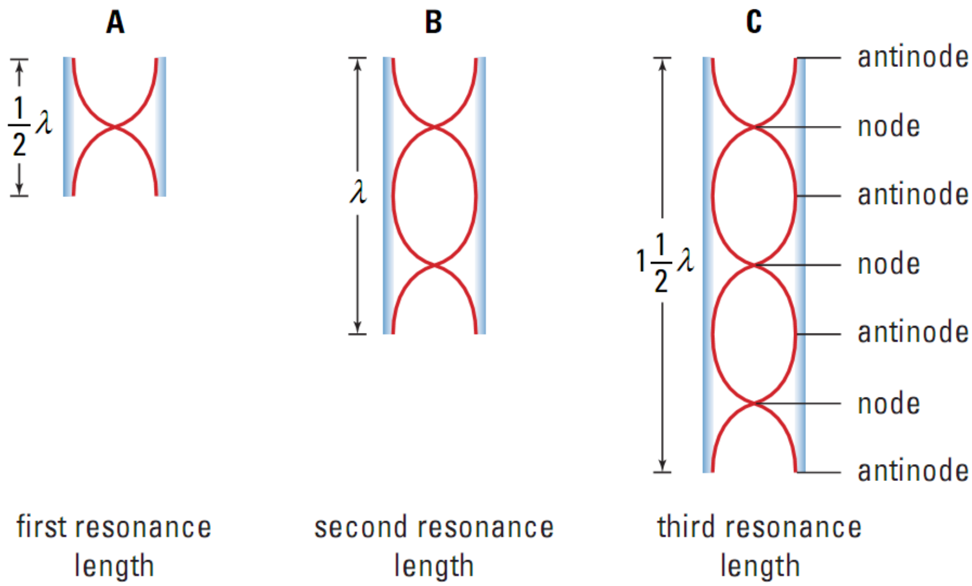


Resonance in a CLOSED Air Column

- Resonance in a Closed Air Column
  - Odd integer multiples of the first resonance length. $(1/4)\lambda$

$$L_n = (2n - 1)\frac{\lambda}{4}$$

Resonance in an OPEN Air Column



Resonance in an OPEN Air Column

- Resonance in an Open Air Column
  - Integral multiples of the first resonance length, (1/2)λ.

$$L_n = \frac{n\lambda}{2}$$

Example Problem

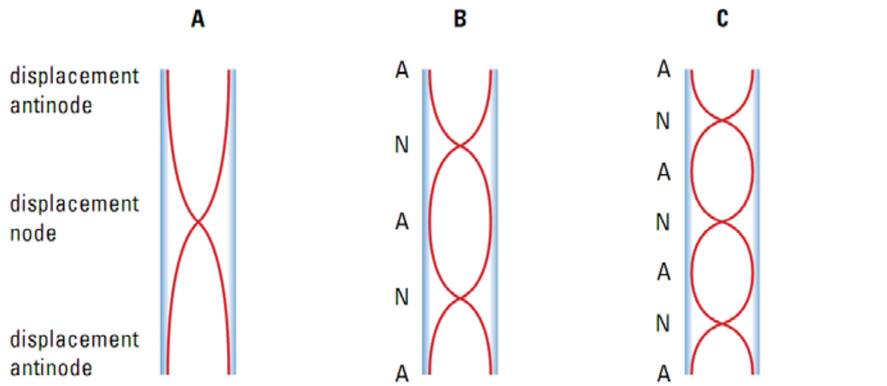
- EX3:
  - A vibrating tuning fork is held near the mouth of a narrow plastic pipe partially submerged in water. The pipe is raised, and the first loud sound is heard when the air column is 9.0cm long. The temperature in the room is 20°C.
    - Calculate the wavelength of the sound produced by the tuning fork.
    - Calculate the length of the air column for the second and third resonances.
    - Estimate the frequency of the tune

Fixed-Length Air Columns

- How does a bugler make different pitches of sound?
  - No valve, keys or slides?
  - How?
  - The vibration of the trumpeters/trombonists 's mouths and lips.

Fixed-Length OPEN Air Columns

- A) Fundamental mode or First Harmonic
- B) First Over-tone or Second Harmonic
- C) 2^{nd} Over-tone or 3^{rd} Harmonic



$\lambda_1 = 2L$ $\qquad$ $\lambda_2 = L$ $\qquad$ $\lambda_3 = \frac{2L}{3}$

$f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$ $\qquad$ $f_2 = \frac{v}{\lambda_2} = \frac{v}{L} = 2f_1$ $\qquad$ $f_3 = \frac{v}{\lambda_3} = \frac{v}{\frac{2L}{3}} = \frac{3v}{2L} = 3f_1$

Resonance Frequencies of a Fixed-Length OPEN Air Columns

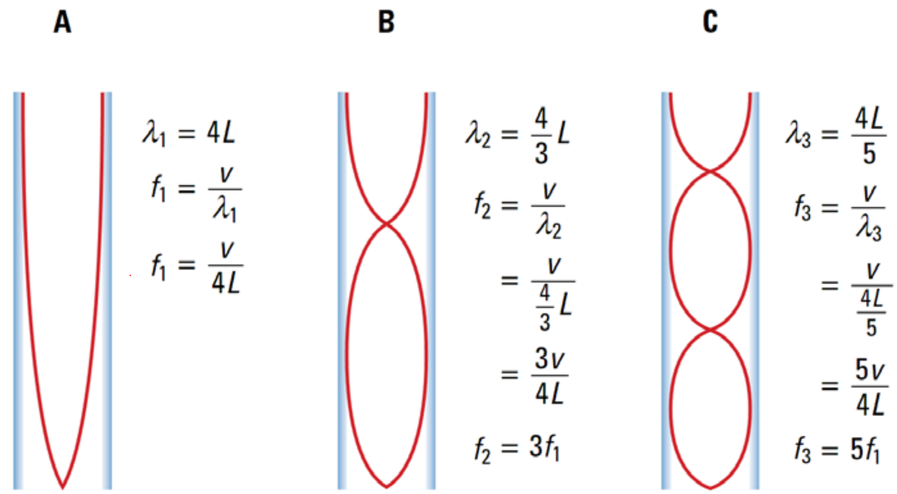
- Resonance Frequencies of a Fixed-Length Open Air Columns
  - Integral multiples of the first resonance frequency, f_1.

$$f_n = nf_1$$

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

Fixed-Length CLOSED Air Columns

- A) Fundamental mode or First Harmonic
- B) First Over-tone or Second Harmonic
- C)2nd Over-tone or 3rd Harmonic



Resonance Frequencies of a Fixed-Length CLOSED Air Columns

- Resonance Frequencies of a Fixed-Length CLOSED Air Columns
  - Odd integer multiples of the first resonance frequency, f_1.

$$f_n = (2n - 1) f_1$$

where $f_1 = \frac{V}{4L}$

Example Problems

- EX4:
  - An air column, open at both ends, has a first harmonic of 330Hz.
    - What are the frequencies of the second and third harmonics?
    - If the speed of sound in air is 344m/s, what is the length of the air column?