Resonance Frequencies for Fixed Length Columns

RESONANCE FREQUENCIES OF A FIXED-LENGTH OPEN AIR COLUMN

The resonance frequencies of a fixed-length open air column are integral multiples of the first resonance frequency, f_1.

$$f_n = nf_1$$

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

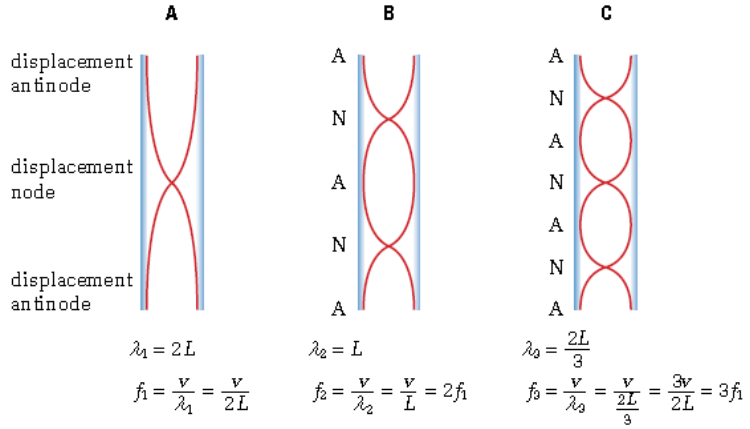

Figure 9.41 **(A)** Fundamental mode or first harmonic; **(B)** first overtone or second harmonic; **(C)** second overtone or third harmonic

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RESONANCE FREQUENCIES OF A FIXED-LENGTH CLOSED AIR COLUMN

The resonance frequencies of a fixed-length closed air column are odd integer multiples of the first resonance frequency, f_1.

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

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

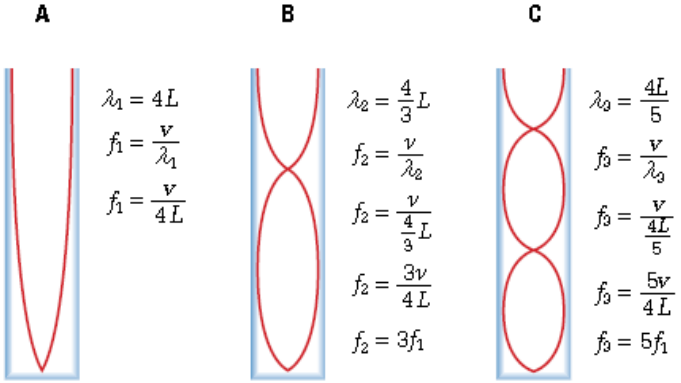

Figure 9.42 **(A)** Fundamental mode or first harmonic; **(B)** first overtone or second harmonic; **(C)** second overtone or third harmonic

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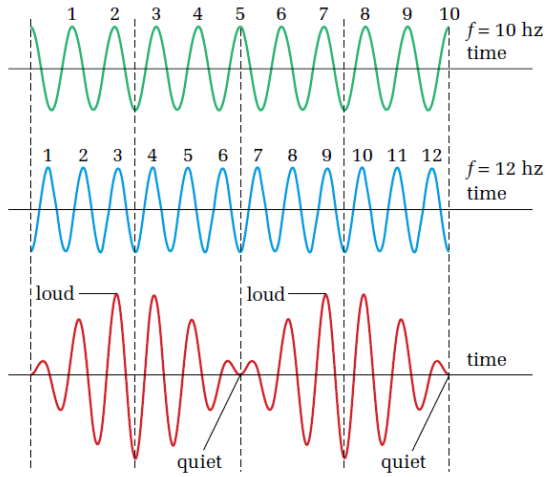
Beats



BEAT FREQUENCY

The beat frequency is the absolute value of the difference of the frequencies of the two component waves.

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

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)

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Harmonics in a Fixed-Length Air Column

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

a) $f_1 = 330\,Hz$ $f_2 = 2(330) = \boxed{660\,Hz}$
$f_3 = 3(330) = \boxed{990\,Hz}$

b) $f_1 = \frac{v}{2L} \Rightarrow 330 = \frac{344}{2L}$

$L = \frac{344}{660} = \boxed{0.52\,m}$

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2. An air column, closed at one end, has a first harmonic of 330 Hz. If the speed of sound in air is 344 m/s, what is the length of the air column?

$$f_1 = \frac{V}{4L} \Rightarrow 330 = \frac{344}{4L}$$

$$L = \frac{344}{1320} = 0.26\text{ m}$$

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Finding the Unknown Frequency

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

$$f_{beats} = |f_2 - f_1| \qquad \frac{46\text{ beats}}{15\text{ sec}} = 3.1\text{ Hz}$$

$$3.1\text{ Hz} \pm 440\text{ Hz}$$

$$436.9\text{ Hz} \text{ or } 443.1\text{ Hz}$$

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