# Physics 115 Lecture 10

More about standing waves

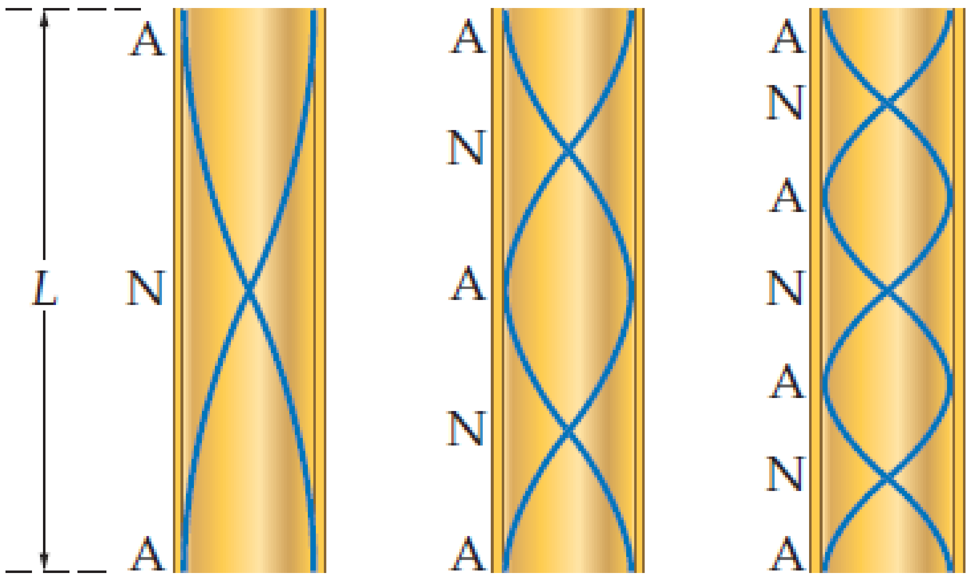
**February 13, 2018**

# Something cool

- Standing sound waves can be used to levitate and manipulate objects!
- Video 1 (D. Foresti – LTNT Switzerland)
- Video 2 (Y. Ochiai – Univ. Tokyo)

# Open tube air columns

- An antinode appears at each open end
- Higher harmonics follow a pattern similar to a string fixed at both ends
- Examples: organ pipe, flute




(a) First harmonic (fundamental)

(b) Second harmonic

(c) Third harmonic

# Open tube air columns

- The effective length of the tube is actually longer than the physical tube. (See https://en.wikipedia.org/wiki/End_correction. For most homework and exam questions you do not need to know this correction. There is not agreement on a universal value; 0.46 works well in our lab.)

$$L = L_{\text{tube}} + 2 \times 0.46 \times R_{\text{tube}}$$

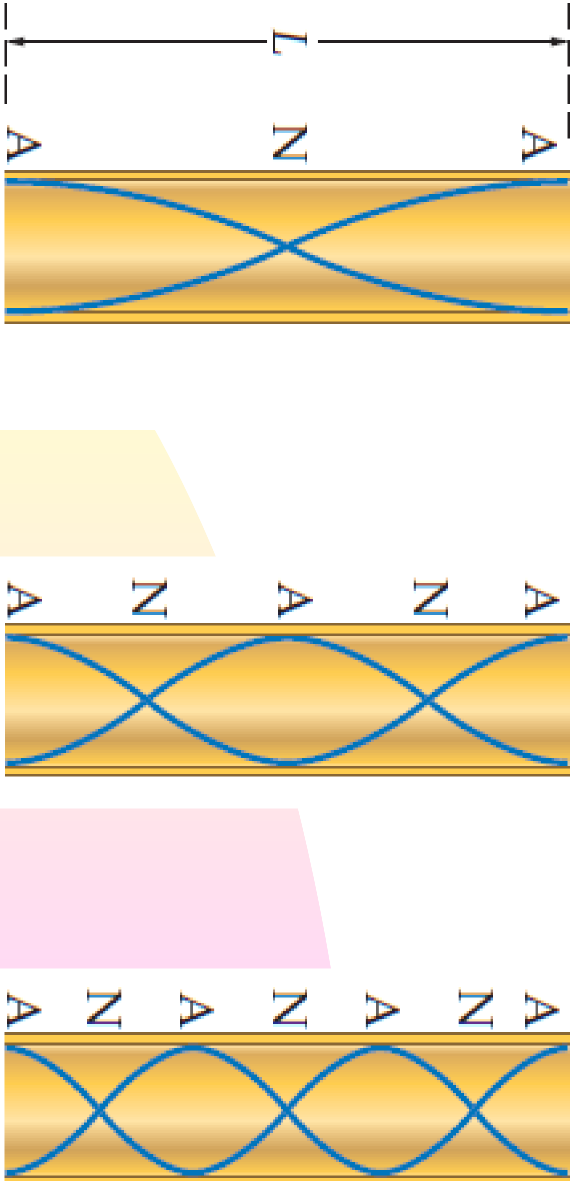
A standard concert flute has $L = 0.610 \text{ m}$ and $R = 0.0095 \text{ m}$.

Ignoring end correction, $f_1 = \dfrac{v}{2L_{\text{tube}}} = \dfrac{343 \text{ m/s}}{2(0.610 \text{ m})} = 281 \text{ Hz}$

Its effective length is $L = 0.610 \text{ m} + 2(0.46)(0.0095 \text{ m}) = 0.6188 \text{ m}$

$f_{1,\text{ actual}} = \dfrac{v}{2L_{\text{tube}}} = \dfrac{343 \text{ m/s}}{2(0.6188 \text{ m})} = 277 \text{ Hz}$, a fourth of a step lower

  - Opening holes in the flute shortens its effective length

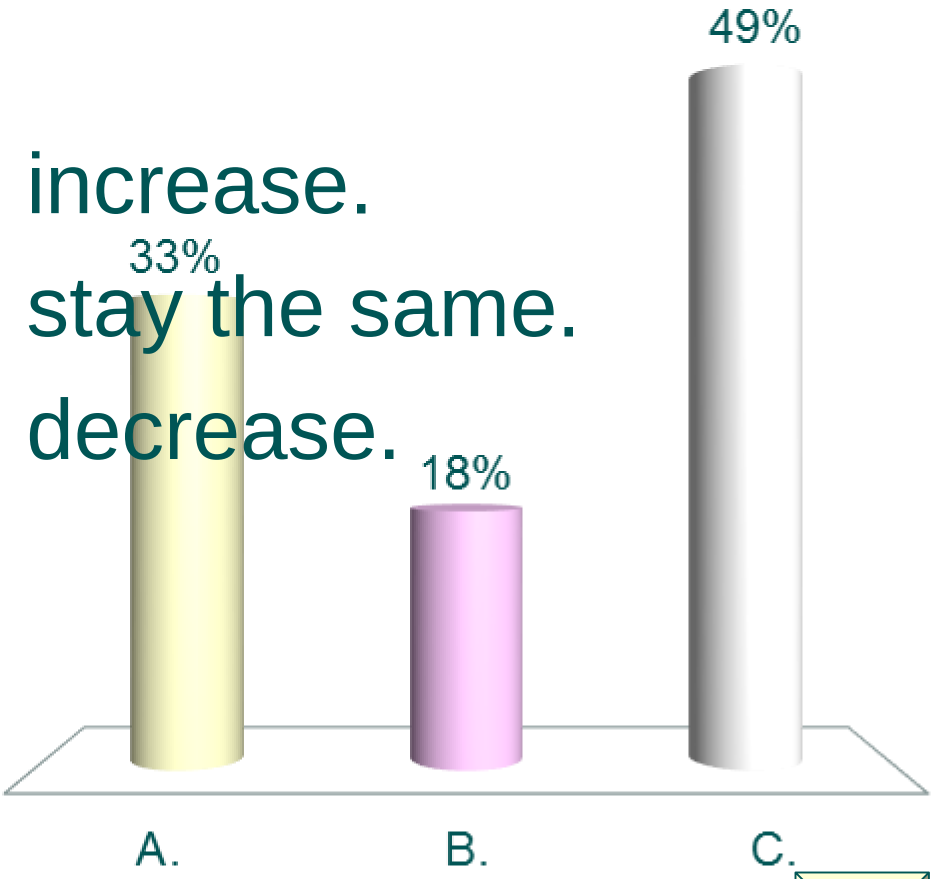



| Harmonic | #antinodes | #nodes | $\lambda$ | $f$ |
|---|---|---|---|---|
| fundamental | 2 | 1 | $\frac{2L}{1}$ | $f_1$ |
| second | 3 | 2 | $\frac{2L}{2}$ | $2\,f_1$ |
| third | 4 | 3 | $\frac{2L}{3}$ | $3f_1$ |

$$c_{\text{air}} = f\lambda$$

## What would happen to the fundamental wavelength of an organ pipe if you fill it with helium (*c* = 1025 m/s) instead of air (*c* = 343 m/s)?

A. The wavelength will increase.
B. The wavelength will stay the same.
C. The wavelength will decrease.



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**What would happen to the fundamental wavelength of an organ pipe if you fill it with helium (*c* = 1025 m/s) instead of air (*c* = 343 m/s)?**

A. The wavelength will increase.

**B. The wavelength will stay the same.**

C. The wavelength will decrease.

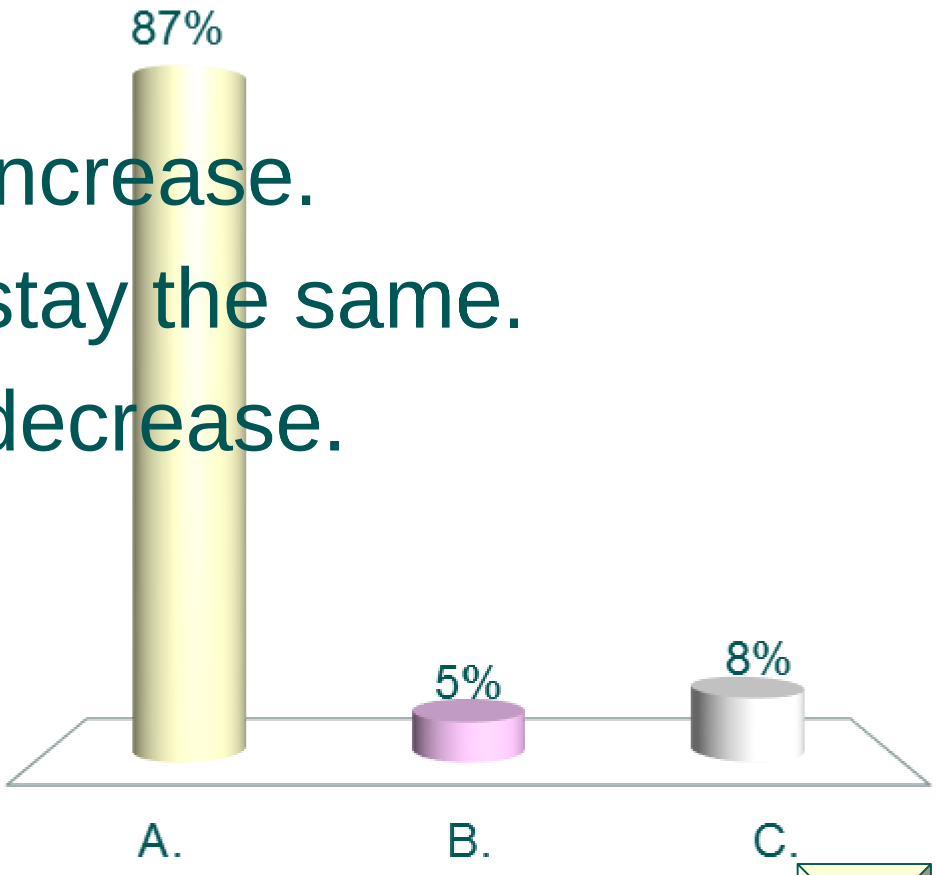
The wavelength is determined by the length of the pipe.

## What would happen to the fundamental frequency of an organ pipe if you fill it with helium ($c$ = 1025 m/s) instead of air ($c$ = 343 m/s)?

A. The frequency will increase.

B. The frequency will stay the same.

C. The frequency will decrease.



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**What would happen to the fundamental frequency of an organ pipe if you fill it with helium ($c$ = 1025 m/s) instead of air ($c$ = 343 m/s)?**

A. **The frequency will increase.**

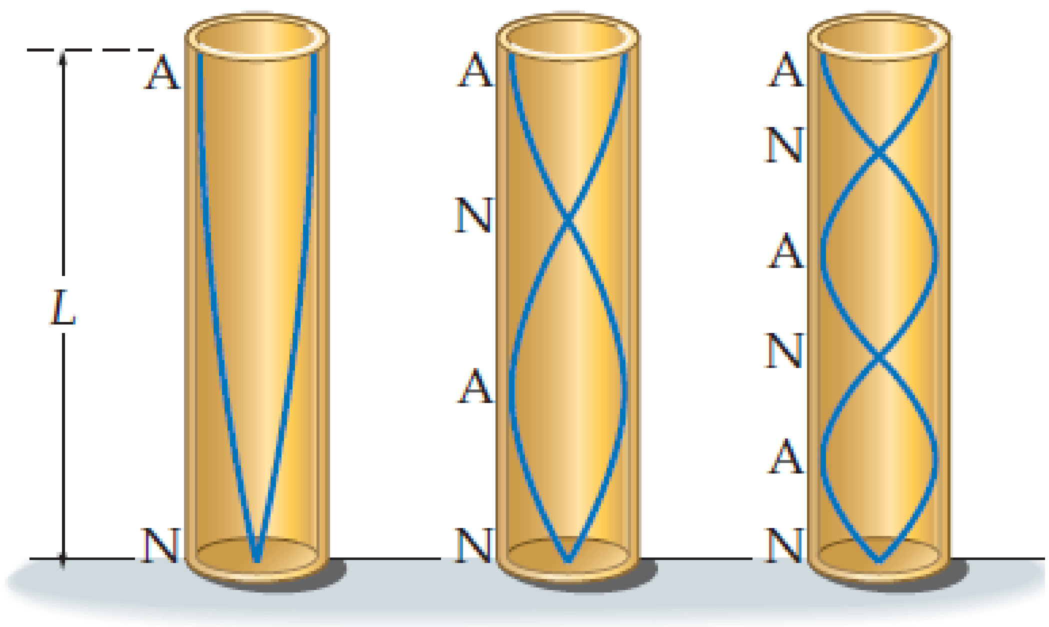
B. The frequency will stay the same.

C. The frequency will decrease.

The speed increases while the wavelength remains the same: $c = f\lambda$

# Closed (at one end) tube air columns

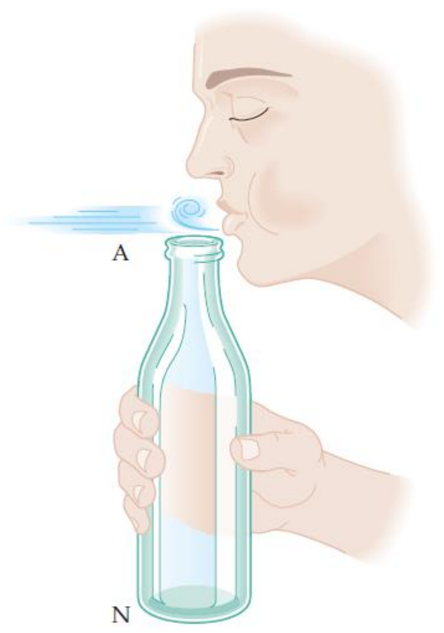
- An antinode appears at the open end, node at the closed end
- Examples: clarinet, trumpet




(a)
First
harmonic
(fundamental)

(b)
Third
harmonic

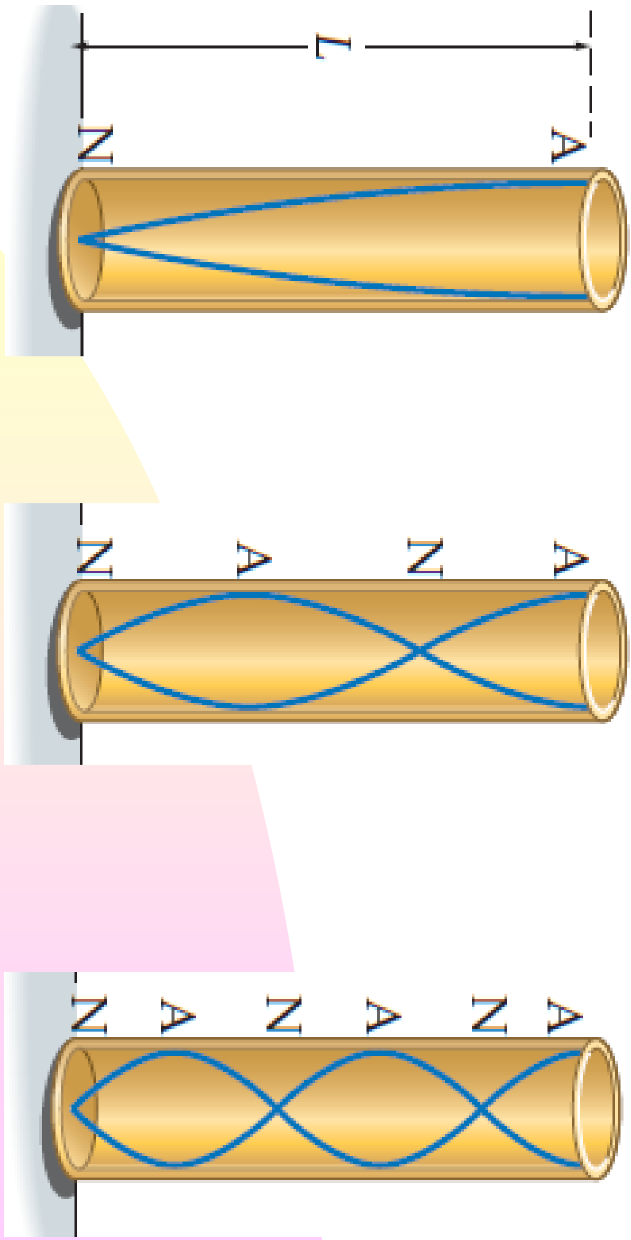
(c)
Fifth
harmonic



# Closed (at one end) tube air columns

- The effective length of the tube is actually longer than the physical tube. (For most homework and exam questions you do not need to know this correction.)
- The end correction only applies to the open end, so the correction is smaller.

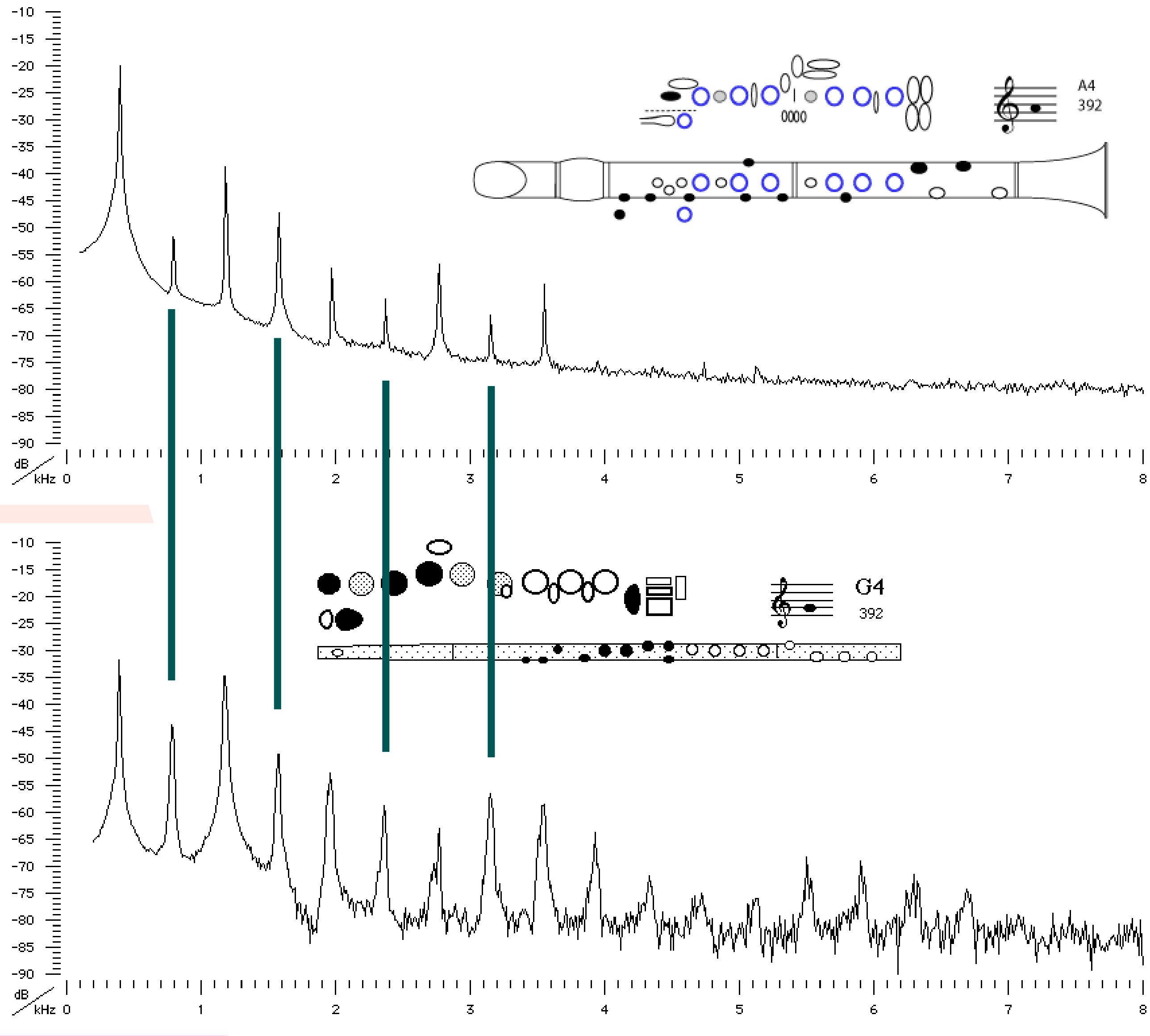
$$L = L_{\text{tube}} + 0.46 \times R_{\text{tube}}$$




| Harmonic | #antinodes | #nodes | $\lambda$ | $f$ |
|---|---|---|---|---|
| fundamental | 1 | 1 | $\frac{4L}{1}$ | $f_1$ |
| third | 2 | 2 | $\frac{4L}{3}$ | $3\,f_1$ |
| fifth | 3 | 3 | $\frac{4L}{5}$ | $5\,f_1$ |

$$c_{\text{air}} = f\,\lambda$$

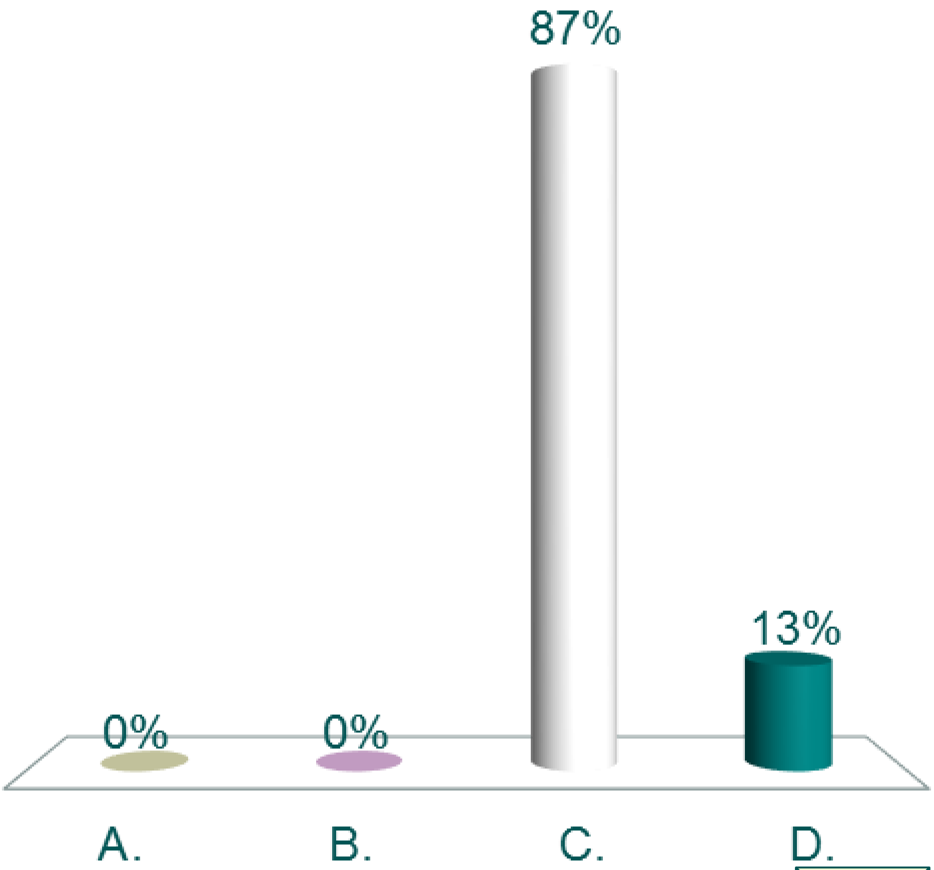
# The even harmonics are "missing" in a closed tube!




See: http://www.phys.unsw.edu.au/jw/flutes.v.clarinets.html

# What is the wavelength of the fifth harmonic standing wave in a 50-cm-long closed organ pipe?

A. 1.00 m
B. 0.50 m
C. 0.40 m
D. 0.20 m



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# What is the wavelength of the fifth harmonic standing wave in a 50-cm-long closed organ pipe?

A. 1.00 m

B. 0.50 m

**C. 0.40 m**

D. 0.20 m

$$\lambda_n = \frac{4L}{n} = \frac{4(0.50\text{ m})}{5} = \boxed{0.40\text{ m}}$$

This would correspond to

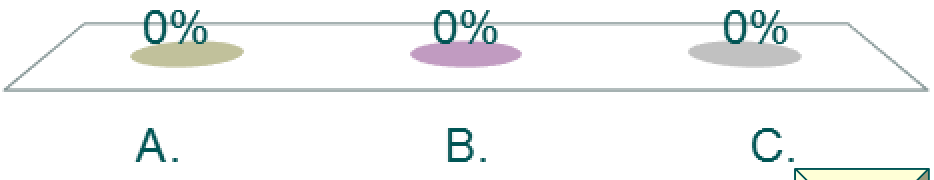
$$f = \frac{c}{\lambda} = \frac{343\text{ m/s}}{0.40\text{ m}} = 858\text{ Hz}$$

**You have an organ pipe that resonates at frequencies of 500, 700, and 900 Hz but nothing in-between. It may resonate at lower and higher frequencies as well. This pipe is**

A. open at both ends.

B. closed at one end.

C. either open or closed, it's impossible to tell with the given information.




Response Counter

90

**You have an organ pipe that resonates at frequencies of 500, 700, and 900 Hz but nothing in-between. It may resonate at lower and higher frequencies as well. This pipe is**

A. open at both ends.

**B. closed at one end.**

The harmonics are separated by 200 Hz. If this were an open pipe, the lowest frequency would thus be 200 Hz. But these frequencies are odd; if you work backwards you find frequencies of 100, 300, 500, 700, 900, 1100 Hz, and so on. Because these are odd multiples of the lowest frequency, we conclude the pipe is closed at one end.

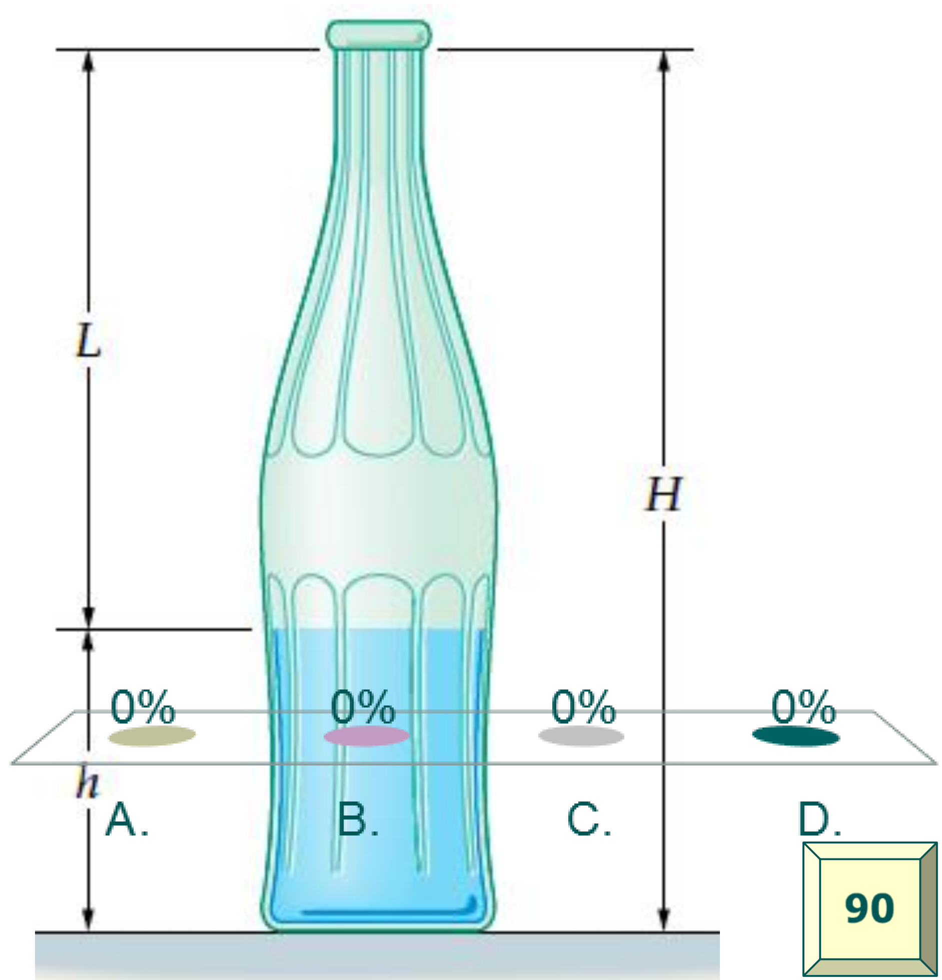
In order to be tuned properly in a band, the fundamental frequency of the bottle must be 440.0 Hz. If the bottle is 26.0 cm tall, how high *h* should it be filled with water? Assume *c* = 343 m/s.

A. 4.4 cm

B. 19.5 cm

C. 39.0 cm

D. 6.5 cm




Response Counter

90

**In order to be tuned properly in a band, the fundamental frequency of the bottle must be 440.0 Hz. If the bottle is 26.0 cm tall, how high *h* should it be filled with water? Assume *c* = 343 m/s.**

A. 4.4 cm

B. 19.5 cm

C. 39.0 cm

**D. 6.5 cm**

$$L = \frac{1}{4}\lambda = \frac{1}{4}\frac{c}{f} = \frac{1}{4}\left(\frac{343\ \text{m/s}}{440.0\ \text{Hz}}\right) = 19.5\ \text{cm}$$

$$h = H - L = 26.0\ \text{cm} - 19.5\ \text{cm} = \boxed{6.5\ \text{cm}}$$