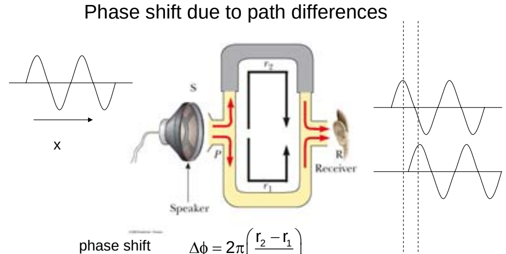
2.1 Standing Waves

Interference of sound waves
Standing waves (waves on a string)
Forced vibrations /Resonance
Standing waves in air columns.

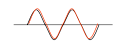
Interference of sound waves

Phase shift due to path differences

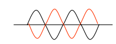


phase shift $\Delta\phi = 2\pi\left(\frac{r_2 - r_1}{\lambda}\right)$

When $r_2 - r_1 = n\lambda$ Constructive Interference



When $r_2 - r_1 = (n+½)\,\lambda$ Destructive Interference



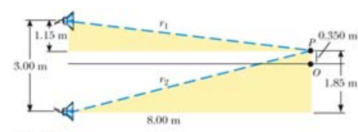
Determining the wavelength of a sound wave – determine the speed of sound

•How does the sound amplitude vary as the path-length difference is varied?

•How can the wavelength be determined?

•How can you determine the speed of sound if the frequency is known?

Example 14.6 Path difference for two sources.



At position P the listener hears the first minimum in sound intensity. Find the frequency of the oscillation.

What is the path difference at O?

What is the phase difference at O?

What is the path difference at P?

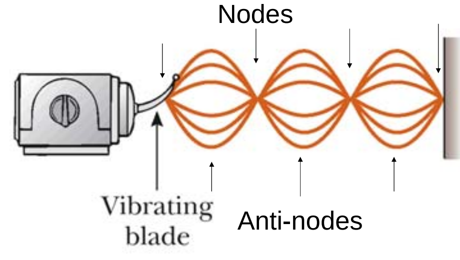
Why is it important that in the question it states that this is the first minimum?
What is the wavelength?

What is the frequency?

Standing Wave

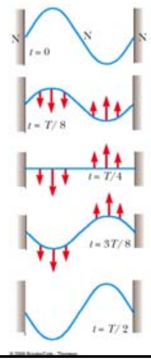
- A standing wave is generated by a traveling wave superimposed on the wave reflected from a boundary.
- Standing waves have a pattern of nodes and anti-nodes.
- The positions of the nodes and anti-nodes are stationary.

Standing waves



Standing Wave – At different times.

The Standing wave doesn't "move" it just stands in one place



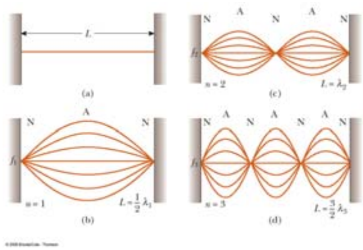
Standing Waves

- A standing wave is generated by superposition of two waves with the same frequency and wavelength traveling in opposite directions.

http://www.walter-fendt.de/ph14e/stwaverefl.htm

Boundary Conditions

- For a wave on a string the two ends must be nodes.
- In addition there can be other nodes in the string.
- The higher the number of nodes the shorter the wavelength.
- The distance between nodes is $d_{NN}=\lambda/2$
- The distance between a node and anti-node is $\lambda/4$



Standing wave frequencies and wavelengths

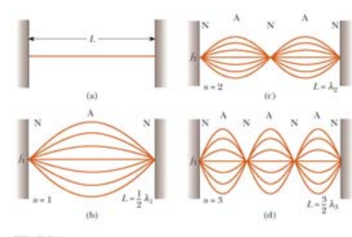
For a string of length L only a specified number of wavelengths and frequencies are allowed.

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

where n = 1, 2, 3......

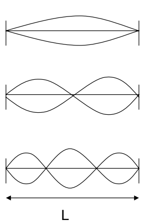
$$\lambda_n = \frac{2L}{n}$$

$$f_n = \frac{v}{\lambda} = \frac{v}{2L}n$$



For n=1 f_1 is called the fundamental frequency or first harmonic.
For n=2 f_2 is called the second harmonic, (or first overtone)

Example 14.8 First part -
Find the fundamental, second and third harmonics of a steel wire 1.00 m long with mass/length = 2.00x10^{-3} kg/m under tension of 80.0 N.



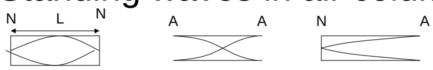
Example 14.8
Second part.

Find the wavelength of the sound in air produced at the fundamental frequency. v=345 m/s How is the wavelength of the sound in air related to the wavelength of the standing wave on the string?

Third part

Suppose the tension in the wire was increased by a factor of 2 . How would the frequency of the fundamental change.

Standing waves in air columns



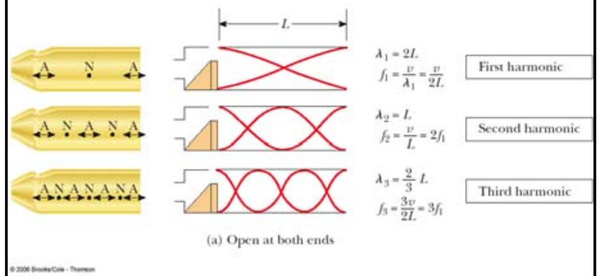
$\lambda_1 = 2L$ $\quad F_1 = \frac{v}{2L}$

$\lambda_1 = 2L$ $\quad F_1 = \frac{v}{2L}$

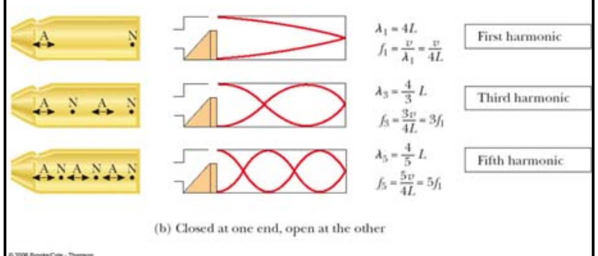
$\lambda_1 = 4L$ $\quad F_1 = \frac{v}{4L}$

- The standing wave is due to sound waves in the column reflected between the two ends.
- The boundary conditions at the ends can either be fixed (closed) or free (open).
- The pattern of frequencies for air columns closed or open at two ends has the same pattern as the wave on a string held at two ends.
- The pattern of frequencies for an air column open at one end and closed at one end is different.

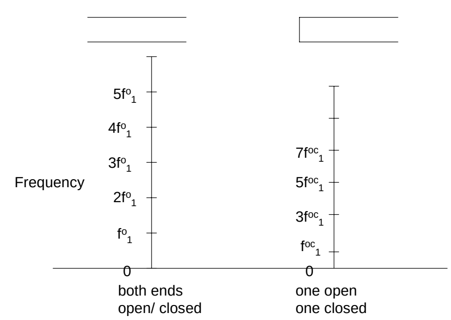
Cylinder open at both ends



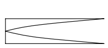
Cylinder open at one end closed at one end



For a cylinder with the same length

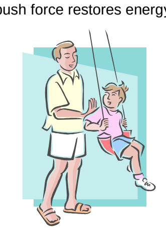


A cylinder 2.5 cm in length is closed at one end and open at the other end. Find the fundamental frequency of the standing wave in the column. v_{air} =340 m/s



Forced vibrations and resonance

The periodic push force restores energy into the system



The push frequency must be at the same frequency as the frequency of the swing. Resonance

What would happen if the push was not at the resonance frequency?

Resonance

When the driving oscillations has a frequency that matches the oscillation frequency of the standing waves in the system then a large amount of energy can be put into the system.