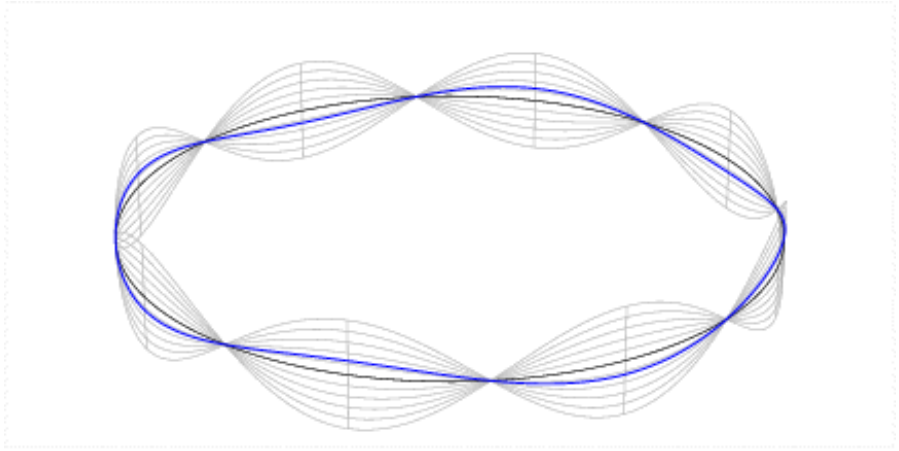
Standing Waves and Resonance

Standing Wave

- There are many example of standing waves in real life

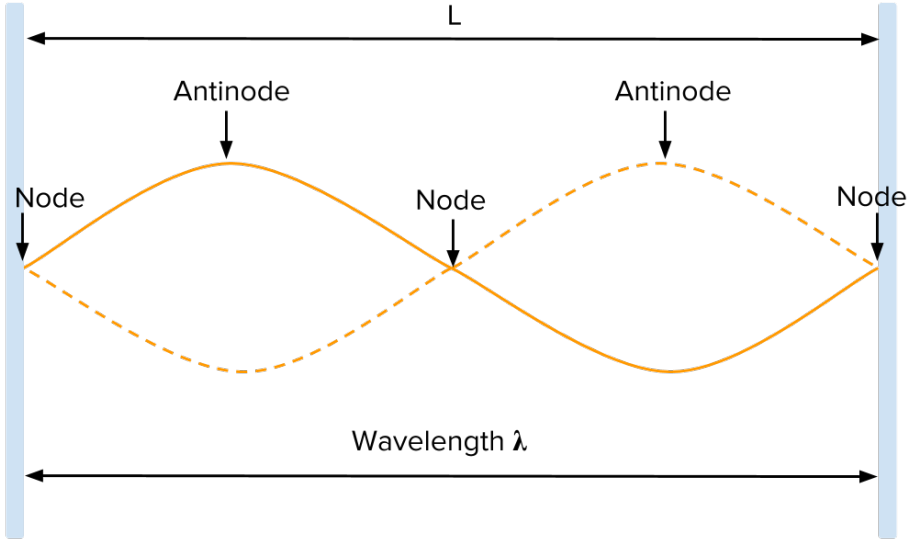


Standing Waves and Resonance

Standing Wave

- Formation of Standing wave:

  A **wave moves along the string or pipe and reflects at the fixed end. The two waves in opposite direction superpose producing a standing wave**



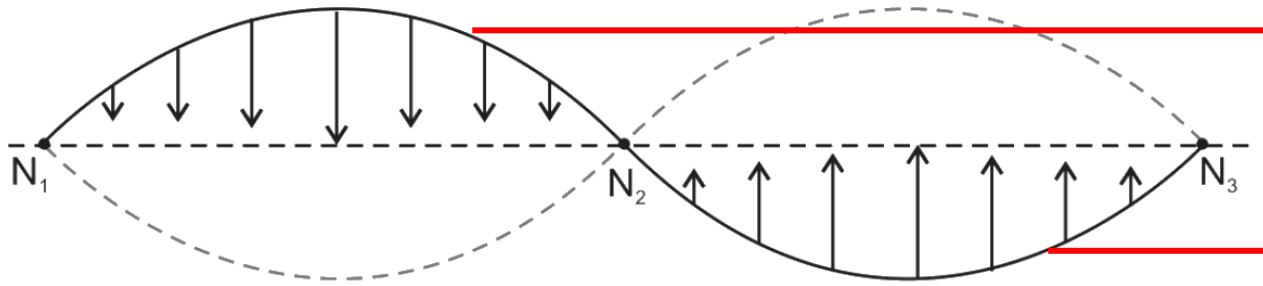
- Formation of node: **Destructive interference** (two waves meet **anti-phase**)
- Formation of antinode: **Constructive interference** (two waves meet **in phase**)

Standing Waves and Resonance

Standing Wave

- Comparison between traveling (progressive) and standing (stationary) waves

	Traveling wave	Standing wave
Amplitude	Same for all points	Different for each point
Phase difference	Varies between points	Points between nodes are in phase
Energy transfer	Energy is transferred along the wave	Energy is stored (trapped) ,not transferred



Phase difference between node: All in phase

Phase difference either side of node: All anti-phase

Standing Waves and Resonance

Standing Wave: Boundary condition

- Standing waves can form on strings or in pipes
- The number of nodes & antinodes depending on:

  1. frequency of wave
  2. **boundary condition**

- Boundary condition:

  1. Fixed at both ends

  2. Free at both ends

  3. One fixed end, one free end

Standing Waves and Resonance

Standing Wave: Boundary condition

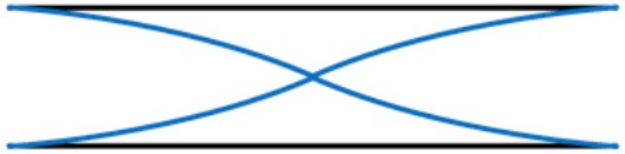
- For a pipe
    - Boundary condition (can be 2 and 3):

      1. Fixed at both ends

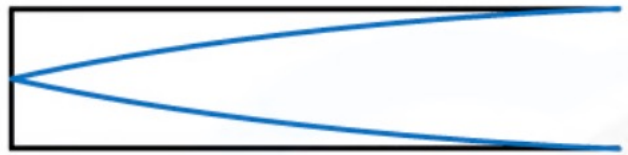
      2. Free at both ends

      3. One fixed end, one free end

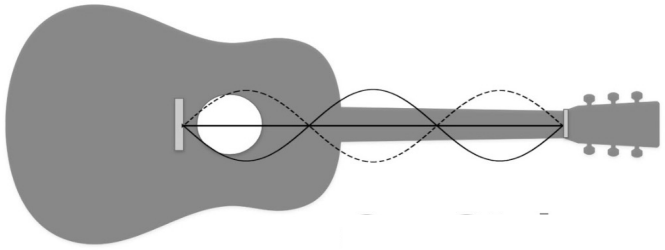
Both fixed ends

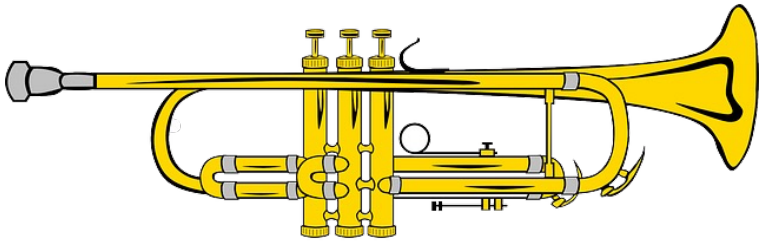


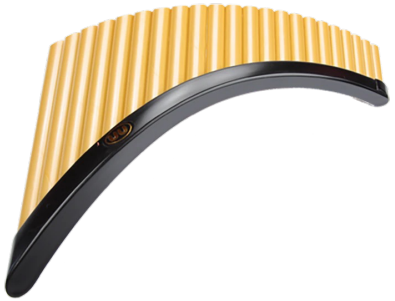
Both free ends



One fixed & one free end







Standing Waves and Resonance

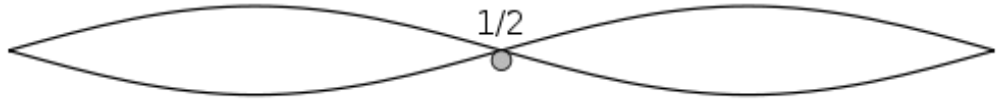
Standing Wave: Boundary condition

- Harmonics: a pattern of standing wave in music

  → Depending on frequency and boundary condition

- **Harmonics on strings:**

  → Boundary condition: both fixed ends



General equation for the harmonics

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

For frequency (natural frequency)

$$f_n = \frac{nv}{2L}$$

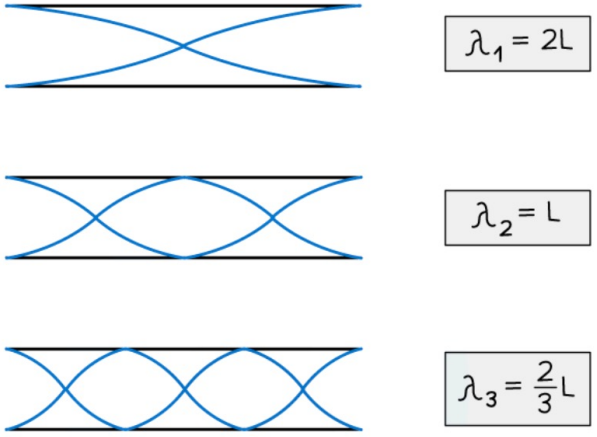
Standing Waves and Resonance

Standing Wave: Boundary condition

- **Harmonics in pipes:**

  → Boundary condition:

  (1) two open ends



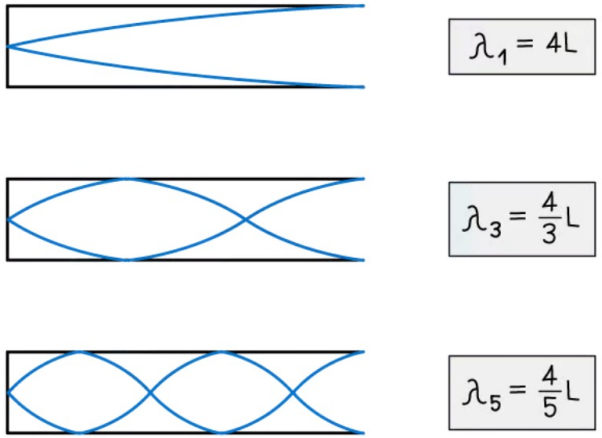
General equation for the harmonics

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

For frequency (natural frequency)

$$f_n = \frac{nv}{2L}$$

(2) One fixed end & one open end



Only odd harmonics can exist

General equation for the harmonics

$$\lambda_n = \frac{4L}{n}$$

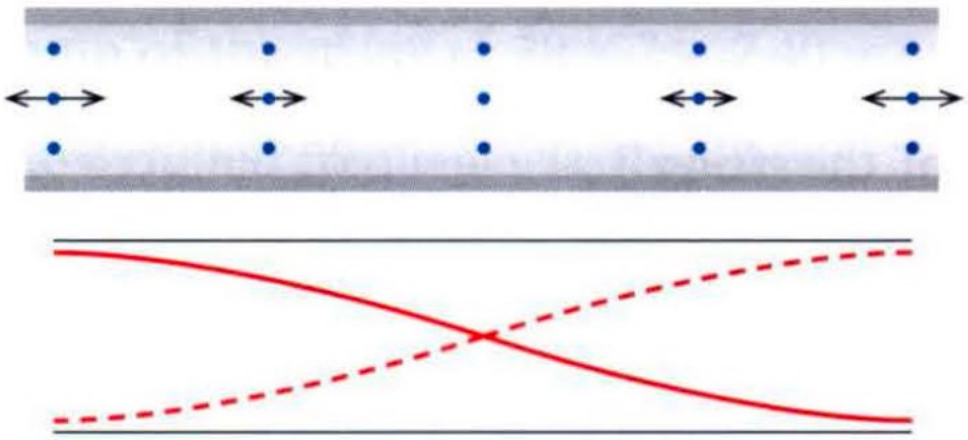
For frequency (natural frequency)

$$f_n = \frac{nv}{4L}$$

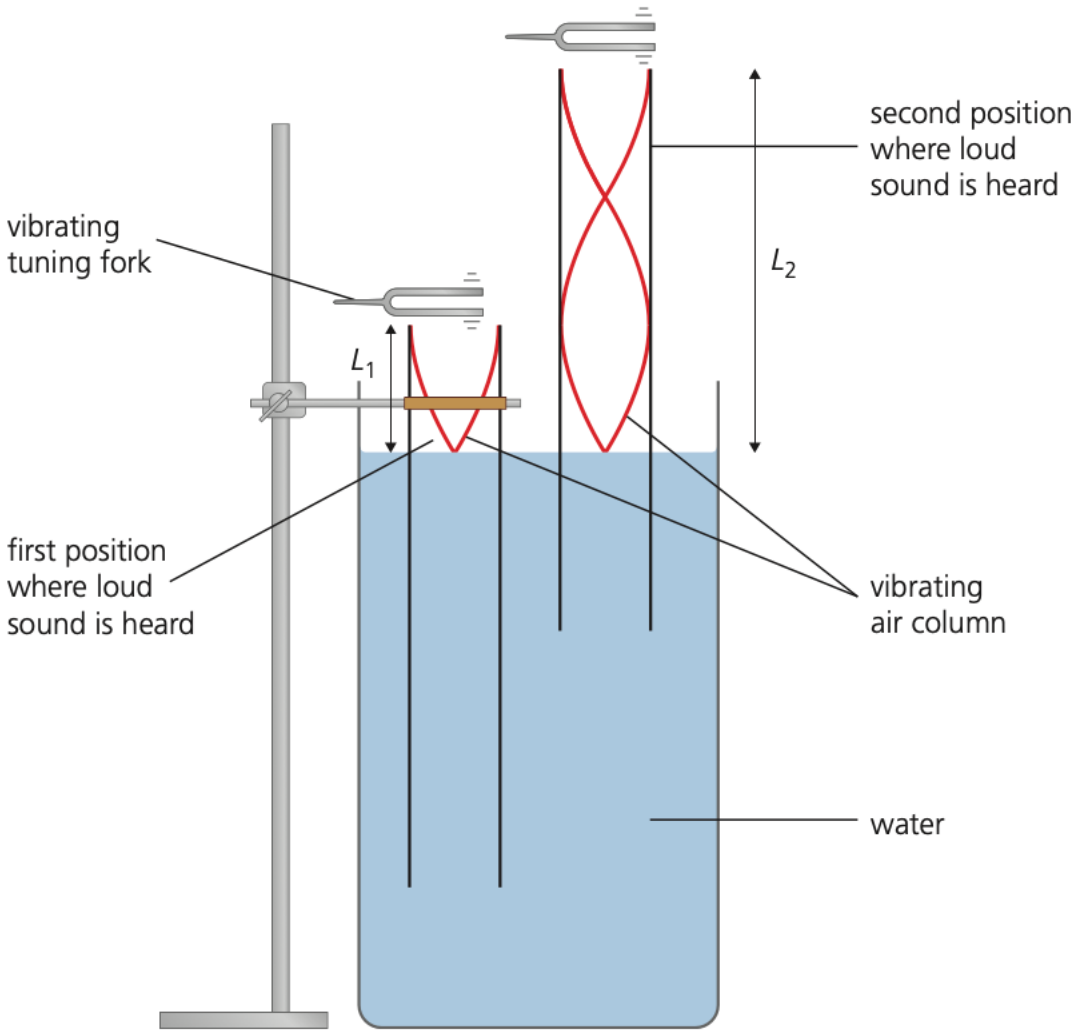
Standing Waves and Resonance

Standing Wave: Boundary condition

- **Molecular explanation**



- Air molecules at node → No oscillation
- Air molecules at antinode → Most oscillation



Standing Waves and Resonance

Example question: Standing wave

A pipe with a single closed end has a standing wave set up within it. If the length of the pipe is 2 m, which value below is closest to the wavelength of the seventh harmonic?

A. 0.345 m

B. 0.782 m

C. 0.983 m

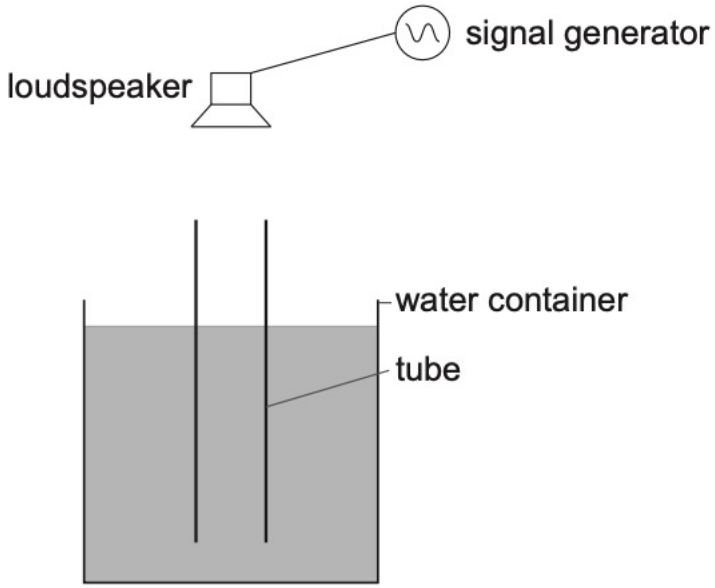
D. 1.14 m

Standing Waves and Resonance

Example question: Standing wave

5. (a) Describe **two** ways in which standing waves differ from travelling waves. [2]

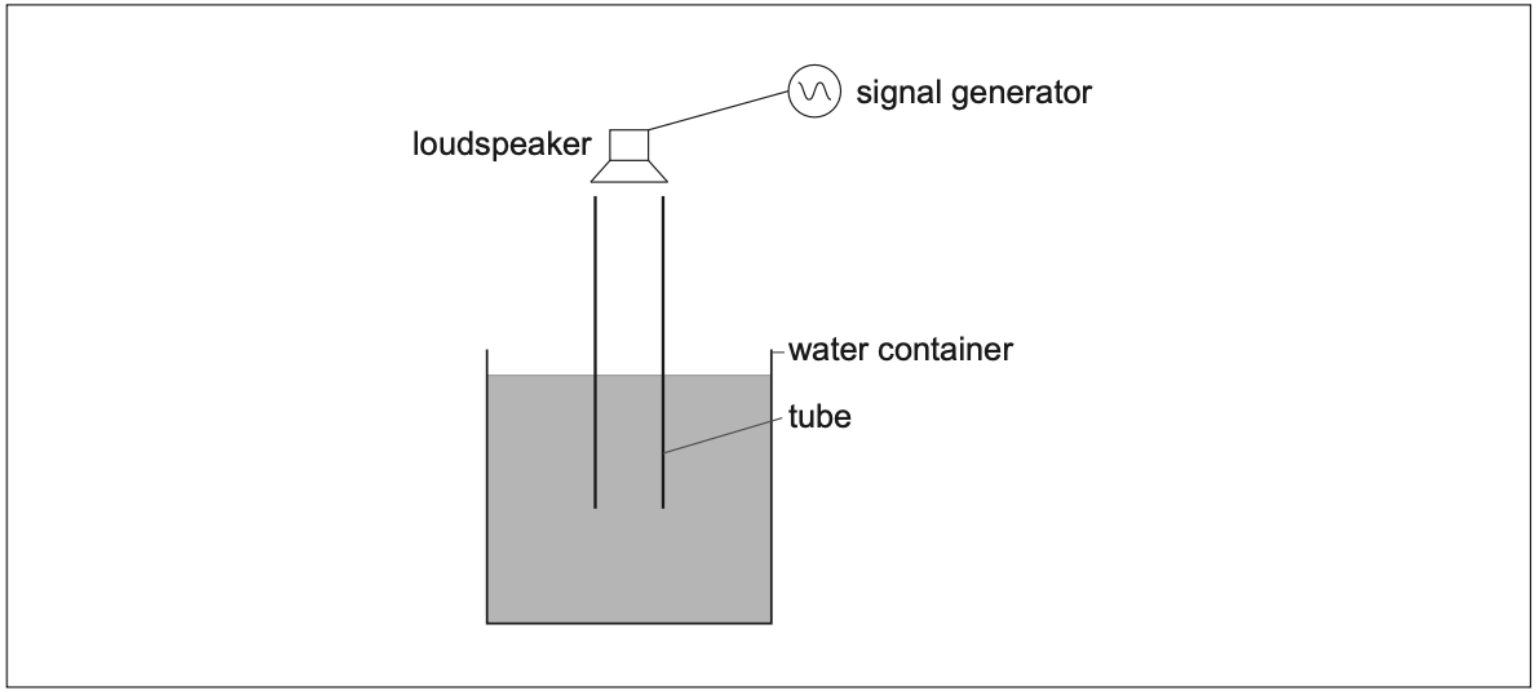
(b) A vertical tube, open at both ends, is completely immersed in a container of water. A loudspeaker above the container connected to a signal generator emits sound. As the tube is raised the loudness of the sound heard reaches a maximum because a standing wave has formed in the tube.



(i) Outline how a standing wave forms in the tube. [2]

(ii) The tube is raised until the loudness of the sound reaches a maximum for a **second time**.

Draw, on the following diagram, the position of the nodes in the tube when the second maximum is heard. [1]



(iii) Between the first and second positions of maximum loudness, the tube is raised through 0.37 m. The speed of sound in the air in the tube is 320 $m\,s^{-1}$. Determine the frequency of the sound emitted by the loudspeaker. [2]