# Standing Waves & Resonance

## Mark Schemes

| | |
|---|---|
| Course | HL IB Physics |
| Section | Wave Behaviour |
| Topic | Standing Waves & Resonance |
| Difficulty | Medium |



To be used by all students preparing for HL IB Physics
Students of other boards may also find this useful

1

The correct answer is **A** because:

- The direction of vibration and propagation of the wave are in the same direction
  - Therefore polarisation is not possible as to block some of the waves will block all of them

2

The correct answer is **A** because:

- When a standing wave is created, no energy will be propagated as the standing wave remains seemingly stationary usually with the overlap of counter-acting inverse waves
- Points along a standing wave oscillate with various amplitudes:
  - Nodes are positions where the amplitude of vibration is zero
  - Antinodes are positions where the amplitude of vibration is maximum
  - Positions between nodes and antinodes oscillate with amplitudes between zero and maximum



**B** is incorrect as a constant amplitude along a standing wave would require that there is no variation between nodes which is incorrect

**C** is incorrect as no energy is transferred by a standing wave, as by their nature they are not moving, but caused by the interference of a wave and its inverse propagating in opposite directions

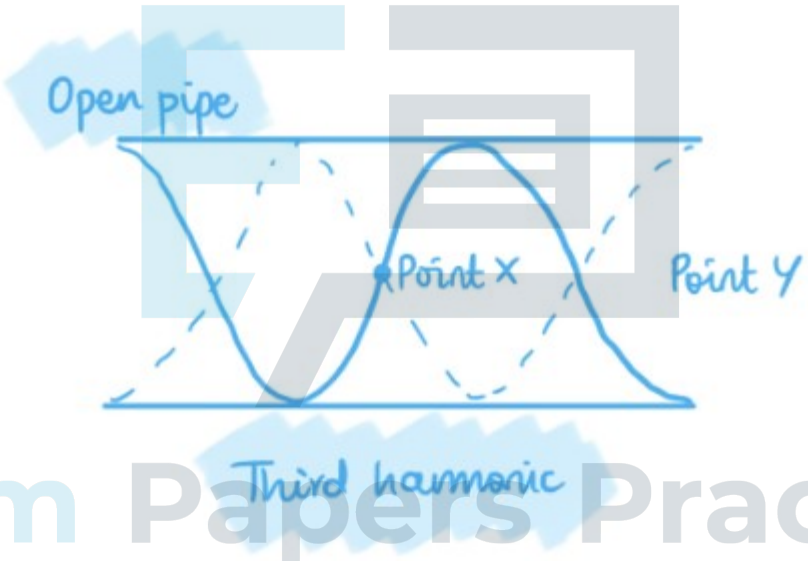
**D** is incorrect as no energy is transferred by a standing wave. They are caused by the interference of a wave and its inverse propagating in opposite directions

3

The correct answer is **B** because:

- During the third harmonic for an open pipe, one and a half wavelengths lie within the pipe. This causes four anti-nodes and three nodes within this standing wave
- The odd number of nodes indicates that a node should be central to this harmonic
- The even number of anti-nodes indicates that anti-nodes should be at the edges of this harmonic
    - Generally, anti-nodes always occur at the open ends of pipes

The below image helps visually show the location of nodes and anti-nodes that occur for the third harmonic in an open pipe.






4

The correct answer is **D** because:

- The frequency for the third harmonic for a pipe or tube which is closed at one end is three times larger than the fundamental frequency which occurs within that space
- In this case, this means: 380 × 3 = 1140 Hz

**A** is incorrect as 127 Hz is smaller than the fundamental frequency which is not possible for a harmonic to occur at since it would be less than the smallest harmonic (the fundamental frequency)

**B** is incorrect as 380 Hz is the same frequency as the fundamental frequency, however a shift in frequency is required to become the third harmonic which has a significant change in pitch (also known as frequency)

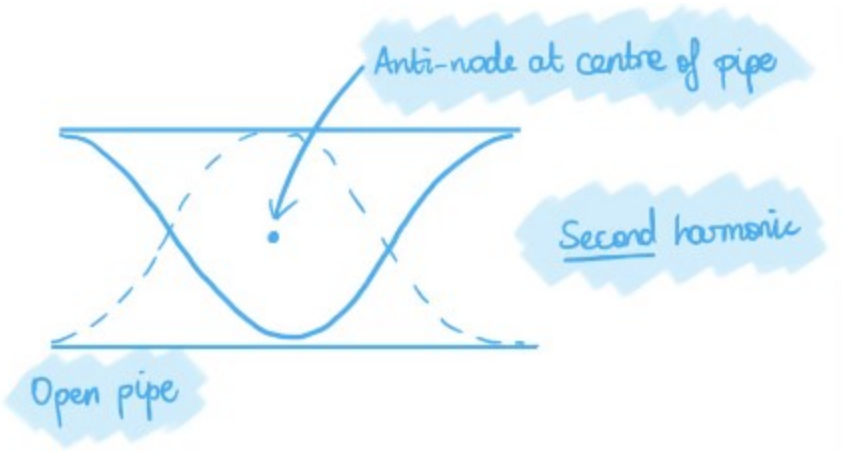
**C** is incorrect as 760 Hz is only twice the magnitude of the fundamental frequency, which is not enough to reach the third harmonic. While the shape of the fundamental frequency is one quarter of a wavelength – with one node and one anti-node - within the pipe or tube. The shape of the third harmonic is three-quarters of a full wavelength – containing two nodes and two anti-nodes - within the pipe or tube and therefore three times the frequency

5

The correct answer is **A** because:

- Due to the nature of the open pipe resonances, there must always be two anti-nodes at the ends of the pipe and an odd number of nodes and anti-nodes between the ends
- For example:
  - In the first harmonic for an open pipe, there are 2 anti-nodes and 1 node. Therefore, the sum of anti-nodes and nodes is 3
  - In the second harmonic for an open pipe, there are 3 anti-nodes and 2 nodes. Therefore, the sum of anti-nodes and nodes is 5
  - In the first harmonic for an open pipe, there are 4 anti-nodes and 3 nodes. Therefore, the sum of anti-nodes and nodes is 7

**B** is incorrect as in the first, third and fifth harmonic for an open pipe, there is a central node. The first occasion when a central anti-node is present is in the second harmonic for an open pipe




**C** is incorrect as this is the opposite of the correct answer and is actually true for pipes with a single closed-end rather than open pipes with both ends open

**D** is incorrect as in the second harmonic for an open pipe, there is a central anti-node

While not mandatory, memorising the shapes of the harmonics within open pipes and those with a single closed-end will help enhance your ability to answer harmonic-based questions. However, the general rule "anti-nodes form at open ends" is a good start to help you figure out shapes of standing waves within them.

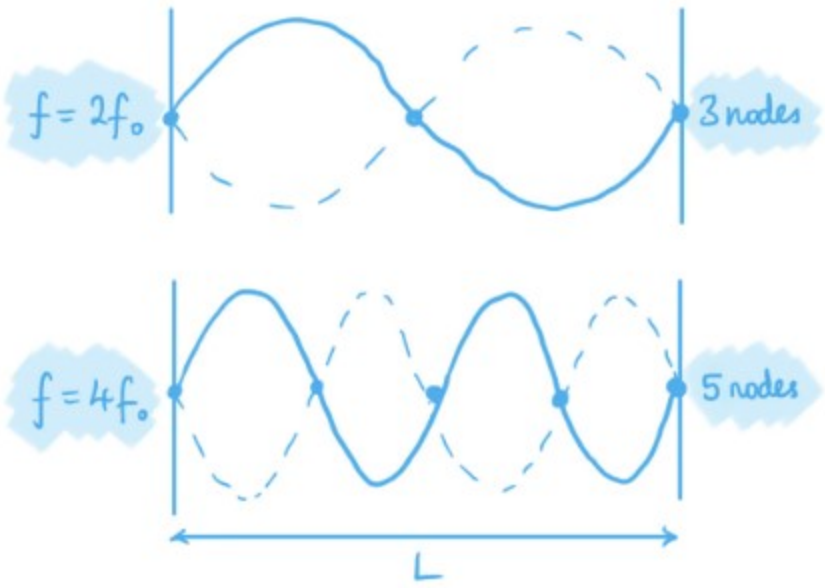


6

The correct answer is **C** because:

- Doubling the frequency will mean that twice the number of wavelengths must lie between the fixed end points of the string
- This would require three nodes between the two-end points which act as the fourth and fifth nodes respectively

Visually the situation when the frequency is doubled will look like the below. Therefore, the five nodes can be visually identified.




7

The correct answer is **C** because:

- For an open pipe the fundamental frequency $f = \frac{v}{2L}$, where $v$ = speed of sound in the medium within the pipe and $L$ = length of pipe
- However, for a single closed end pipe of the same length, the fundamental frequency is given by: $f = \frac{v}{4L}$
- Since the open pipe is divided by $2L$ and the single closed-end pipe is divided by $4L$, the frequency of the open pipe will be twice as large as that of the pipe with a single closed-end
    - Therefore, the ratio of the fundamental frequencies for the open end pipe to the closed end pipe is 2:1

8

The correct answer is **D** because:

- The seventh harmonic for a pipe with a single closed end will have a wavelength $\lambda_7 = \frac{4L}{7}$, where $L$ is the length of the pipe
- Therefore, the wavelength will be approximately $\frac{4}{7} \times 2 \approx 1.14$ m

While not mandatory, memorizing the equations of the harmonics within open pipes and those with a single closed-end will help enhance your ability to answer harmonic-based questions.

9

The correct answer is **B** because:

- Since this is an open pipe, the fundamental frequency will have a frequency that is related the velocity of the wave and the length of the pipe
- This relationship is given by: $f_1 = \frac{v}{2L}$ where:
  - $f_1$ = the frequency of the first harmonic
  - $v$ = the velocity of the wave
  - $L$ = the length of the pipe
- Therefore, the length of the pipe can be given by: $L = \frac{v}{2f_1}$
  - $v$ is the speed of sound in air = 343 m s$^{-1}$
  - $f_1$ = 400 Hz as given in the question
- So, the approximate length of the pipe is: $L = \frac{343}{2 \times 400} \approx 0.43$ m

While not mandatory, memorizing the equations of the harmonics within open pipes and those with a single closed-end will help enhance your ability to answer harmonic-based questions.

10

The correct answer is **C** because:

- Since this is a pipe with a single closed end and one open end, the fifth harmonic frequency will have a frequency that is related the velocity of the wave and the length of the pipe. This relationship is given by: $f_5 = \frac{5v}{4L}$ where:
  - $f_5$ = The frequency of the fifth harmonic (Hz)
  - $v$ = the velocity of the wave
  - $L$ = the length of the pipe
- So, the approximate frequency of the fifth harmonic $f_5 = \frac{5 \times 343}{4 \times L} \approx 429 \div L$

While not mandatory, memorizing the equations of the harmonics within open pipes and those with a single closed-end will help enhance your ability to answer harmonic-based questions.