16. The wavelength of a standing (stationary) wave is equal to

A. the distance between adjacent nodes.

B. twice the distance between adjacent nodes.

C. half the distance between adjacent nodes.

D. the distance between a node and an adjacent antinode.

15. Which of the following statements is true for a standing wave on a string?

A. No energy is transferred along the string.

B. The maximum kinetic energy of each segment of the string is proportional to the amplitude of the segment.

C. Each segment of the string oscillates with different phase and frequency.

D. The amplitude along the string varies with time.

18. The fundamental (first harmonic) frequency of the note emitted by an organ pipe closed at one end is f. What is the fundamental frequency of the note emitted by an organ pipe of the same length that is open at both ends?

A. $\frac{f}{4}$

B. $\frac{f}{2}$

C. $2f$

D. $4f$

12. An organ pipe of length L is open at one end and closed at the other. Which of the following gives the wavelength of the second harmonic standing wave in the pipe?

A. $\frac{L}{2}$

B. L

C. $4L$

D. $\frac{4L}{3}$

13. The fundamental (first harmonic) frequency for a particular organ pipe is 330 Hz. The pipe is closed at one end but open at the other. What is the frequency of its next highest harmonic?

A. 110 Hz

B. 165 Hz

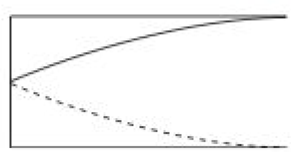
C. 660 Hz

D. 990 Hz

15. A string vibrates with fundamental frequency f. The wavelength of the sound produced in air is λ. Which of the following correctly gives the frequency of vibration of the fourth harmonic of the string and the wavelength of the sound in air?

	Frequency	**Wavelength**
A.	$\frac{f}{2}$	$\frac{\lambda}{4}$
B.	$4f$	4λ
C.	$\frac{f}{2}$	4λ
D.	$4f$	$\frac{\lambda}{4}$

13. A standing wave of frequency f is established in air in a pipe open at one end, as shown.



Which of the following is the frequency of the next highest harmonic?

A. $\frac{f}{3}$

B. $\frac{f}{2}$

C. $2f$

D. $3f$

16. The air in a pipe, of length l and open at both ends, vibrates with a fundamental frequency f. What is the fundamental frequency of a pipe of length $1.5l$ and closed at one end?

A. $\frac{f}{3}$

B. $\frac{2f}{3}$

C. $\frac{3f}{2}$

D. $3f$

A2. This question is about standing waves on strings.

(a) A string is fixed at one end and the other free end is moved up and down. Explain how a standing wave can be formed on the string. *[3]*

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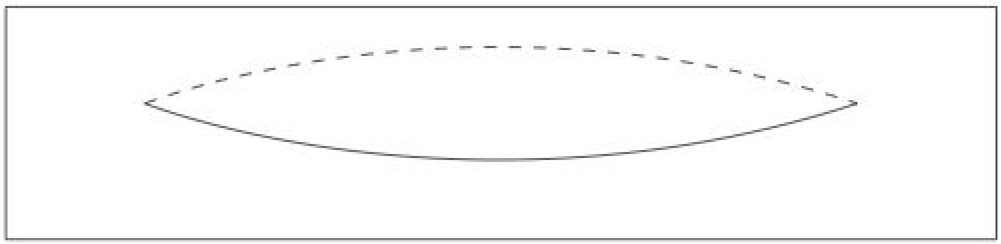
(b) The diagram shows a string vibrating in its fundamental (first harmonic) mode. Both ends of the string are fixed.



(i) Label an antinode on the diagram. *[1]*

(ii) The length of the string is 0.85 m and its fundamental frequency is 73 Hz. Calculate the speed of the waves on the string. *[2]*

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(iii) Sketch how the string will appear if it is vibrated at a frequency three times that of the fundamental frequency. *[1]*

(iv) State the speed of the wave when the string is vibrated at a frequency three times that of the fundamental frequency. *[1]*

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A2. This question is about standing (stationary) waves.

(a) State **one** way in which a standing wave differs from a travelling (progressive) wave. *[1]*

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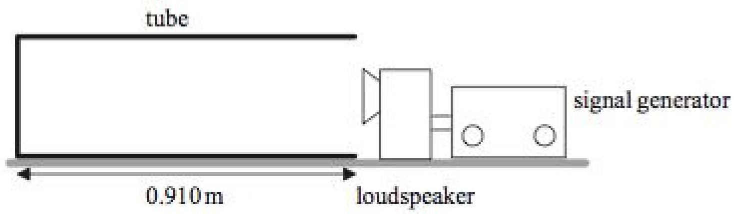
(b) A loudspeaker connected to a signal generator is placed in front of the open end of a tube.



The frequency of the sound is slowly increased from zero. At a frequency of 92.0 Hz the first large increase in the intensity of the sound is heard.

(i) On the diagram above, draw a representation of the wave in the tube for the frequency of 92.0 Hz. *[1]*

(ii) The length of the tube is 0.910 m. Determine the speed of sound in the tube. *[2]*

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A2. This question is about standing waves.

A string is attached between two rigid supports and is made to vibrate at its fundamental frequency (first harmonic) f.

The diagram shows the displacement of the string at $t = 0$.

(a) Draw the displacement of the string at time

(i) $t = \dfrac{1}{4f}$ *[1]*

(ii) $t = \dfrac{1}{2f}$ *[1]*

(b) The distance between the supports is 1.0 m. A wave in the string travels at a speed of $240\,\mathrm{m\,s^{-1}}$. Calculate the frequency of the vibration of the string. *[2]*

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(c) An organ pipe that is open at one end has the same fundamental frequency as the string in part (b). The speed of sound in air is $330\,\mathrm{m\,s^{-1}}$. Determine the length of the pipe. *[2]*

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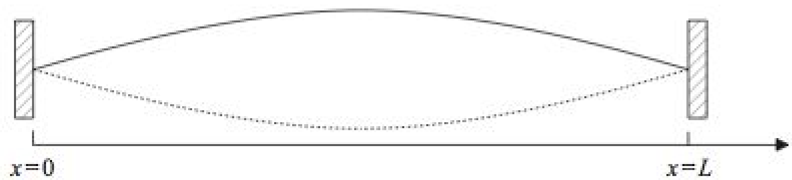
A2. This question is about standing waves.

A string that is fixed at both ends is made to vibrate in the fundamental (first harmonic) mode.



The fixed ends of the string are at $x=0$ and $x=L$.

Each point on the string oscillates in simple harmonic motion. The displacement y of the string at a point x at time t is given by the equation

$$y = A\cos(500\pi t)$$

where $A = 12\sin\left(\frac{\pi x}{2}\right)$.

In these formulae x is in metres and t is in seconds. Using this equation,

(a) explain why the amplitude of the standing wave is not constant. *[1]*

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(b) calculate the frequency of the standing wave. *[2]*

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(c) show that $L = 2.0$ m. *[1]*

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A1. This question is about standing (stationary) waves.

(a) Describe **two** ways that standing waves are different from travelling waves. *[2]*

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2. . . . .

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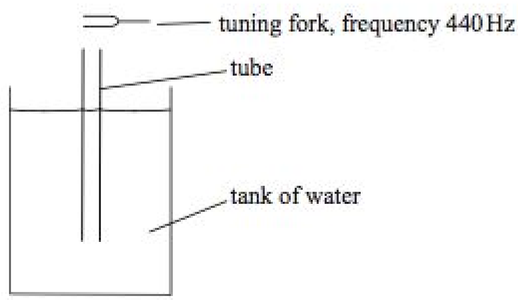
(b) An experiment is carried out to measure the speed of sound in air, using the apparatus shown below.



A tube that is open at both ends is placed vertically in a tank of water, until the top of the tube is just at the surface of the water. A tuning fork of frequency 440 Hz is sounded above the tube. The tube is slowly raised out of the water until the loudness of the sound reaches a maximum for the first time, due to the formation of a standing wave.

(i) Explain the formation of a standing wave in the tube. *[2]*

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(ii) State the position in the tube that is always a node. *[1]*

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(iii) The tube is raised a little further. Explain why the loudness of the sound is no longer at a maximum. *[3]*

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(c) The tube is raised until the loudness of the sound reaches a maximum for a second time. Between the two positions of maximum loudness, the tube has been raised by 36.8 cm. The frequency of the sound is 440 Hz. Estimate the speed of sound in air. *[2]*

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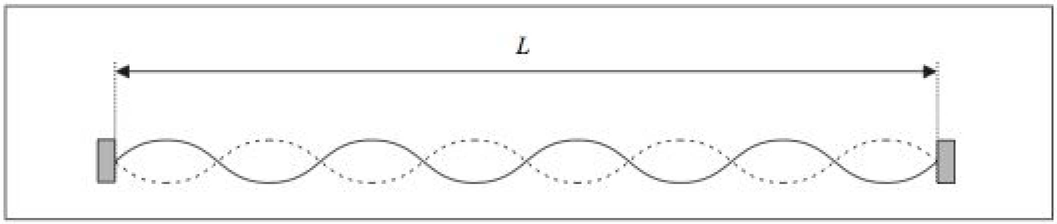
A1. This question is about standing (stationary) waves.

The diagram represents a standing wave of wavelength λ set up on a string of length L.



The string is fixed at both ends.

(a) For this standing wave

(i) state the relationship between λ and L. *[1]*

. . . .

(ii) label, on the diagram, **two** antinodes where the string is vibrating in phase. Label the antinodes with the letter A. *[2]*

(b) The standing wave has wavelength λ and frequency f. State and explain, with respect to a standing wave, what is represented by the product $f\lambda$. *[3]*

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16 B
15 A
18 C
12 D
13 D
15 D
13 D
16 A

A2. (a) at certain fixed frequencies;
incident wave and reflected wave;
superpose (or interfere); *[3]*

(b) (i) antinode clearly labelled in centre; *[1]*

(ii) wavelength = 1.7 m;
speed = 1.2×10^2 m s^{-1}; *[2]*

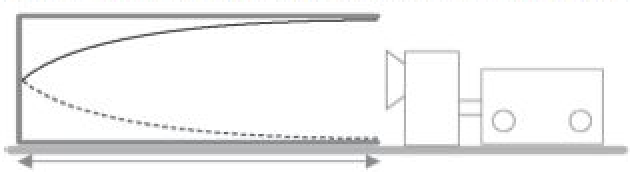
(iii)

[1]

(iv) 1.2×10^2 m s^{-1}; *[1]*

A2. (a) standing waves do not transfer energy;
standing waves do not have a constant amplitude;
points on a standing wave between consecutive nodes have a constant phase;
standing waves have permanent nodes/antinodes; *[1 max]*

(b) (i) correct diagram as shown; *(dotted line not essential for the mark)* *[1]*



(ii) wavelength of sound is $(4 \times 0.910) = 3.64\,\text{m}$;
speed of sound $3.64 \times 92 = 335\,\text{m s}^{-1}$; *[2]*

(c) the next harmonic has wavelength $\frac{4 \times 0.910}{3} = \frac{3.64}{3}\,\text{m}$;
and so frequency $3 \times 92 = 276\,\text{Hz}$; *[2]*

A2. (a) (i) ; *[1]*

(ii) ; *[1]*

(b) $f=\frac{v}{\lambda}$;
to give $f=120\,\text{Hz}$; *[2]*

(c) $\lambda=4L=\left(\frac{330}{120}\right)$;
$L=0.69\,\text{m}$; *[2]*

A2. (a) (comparison with the SHM displacement formula shows that) the amplitude is *A* and this depends on *x*; *[1]*

(b) frequency is $\frac{500\pi}{2\pi}$;
$f=250\,\text{Hz}$; *[2]*

(c) at $x=2.0\text{m}$, the amplitude is always equal to $A=12\sin\pi=0$ as required for a node; *[1]*

A1. (a) energy is propagated by travelling waves / energy is not propagated by standing waves;
amplitude constant for travelling waves / amplitude varies with position for standing waves;
phase varies with position for travelling waves / phase constant for standing waves;
travelling waves do not have nodes and antinodes / standing waves do have nodes and antinodes;
travelling waves can have any wavelength/frequency / standing waves can only have certain wavelengths/frequencies (to fit boundary conditions); *[2 max]*

(b) (i) wave from tuning fork travels down tube and is reflected;
incident and reflected waves interfere/superpose/combine/add together to give a standing wave (that fits the boundary conditions); *[2]*

(ii) the surface of the water (in/at the bottom of the tube); *[1]*

(iii) the length of the air column has changed;
boundary conditions can no longer be met / the length is no longer equal to one quarter of a wavelength;
hence a standing wave cannot form / resonance no longer occurs / natural frequency of air column no longer equal to frequency of sound; *[3]*

(c) $\frac{\lambda}{2}=0.368\Rightarrow\lambda=0.736\,\text{m}$;
$v=f\lambda=440\times0.736=320\,\text{m s}^{-1}$; *[2]*

A1. (a) (i) $L = 4\lambda$ ***or*** $\lambda = \frac{L}{4}$; ***[1]***

(ii) two antinodes labelled;
with separation of integral number of wavelengths; ***[2]***

(b) $f\lambda$ is the speed of the wave;
standing wave formed by interference of an incident and a reflected progressive wave;
speed is the speed of this progressive wave; ***[3]***