Physics A (H156, H556)

Exploring - Stationary waves ppq
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Please note that you may see slight differences between this paper and the original.

Candidates answer on the Question paper.

OCR supplied materials:
Additional resources may be supplied with this paper.

Other materials required:
- Pencil
- Ruler (cm/mm)

Duration: Not set

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions, unless your teacher tells you otherwise.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Where space is provided below the question, please write your answer there.
- You may use additional paper, or a specific Answer sheet if one is provided, but you must clearly show your candidate number, centre number and question number(s).

INFORMATION FOR CANDIDATES

- The quality of written communication is assessed in questions marked with either a pencil or an asterisk. In History and Geography a *Quality of extended response* question is marked with an asterisk, while a pencil is used for questions in which *Spelling, punctuation and grammar and the use of specialist terminology* is assessed.
- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **37**.
- The total number of marks may take into account some 'either/or' question choices.

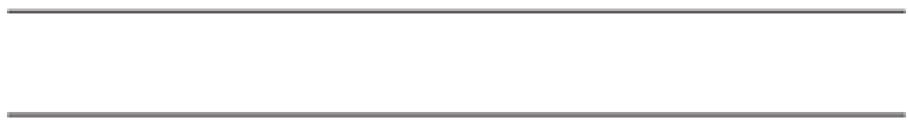
1(a) The figure below represents a tube open at both ends.

Air inside the tube is forced to oscillate by a speaker and produces a standing wave.

The length of the tube is 30.0 cm.

The wave speed inside the tube is 340 ms^{-1}.

On The figure sketch the standing wave for the fundamental mode of vibration.



[1]

(b) Calculate the frequency f_0 of the speaker that is producing the standing wave inside the tube.

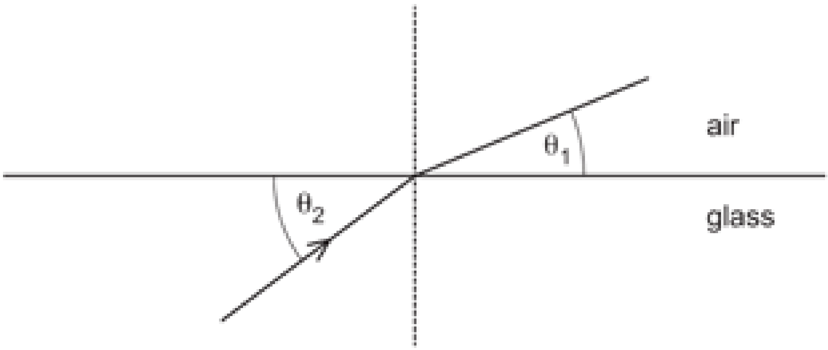
f_0 = ... Hz **[1]**

(c) The frequency of the speaker is increased.

Calculate the next frequency f_1 that will produce a standing wave in this tube.

f_1 = ... Hz **[2]**

2 A ray of light is travelling through glass with refractive index n = 1.51. The diagram (not to scale) shows light incident on a glass / air interface.



Which of these statements is/are true?

1 wavelength of light in glass < wavelength of light in air

2 $n_{glass} = 2n_{air}$

3 $\theta_2 > 48°$

A 1 only

B 1 and 2

C 3 only

D 1 and 3

Your answer [1]

3 A student is doing an experiment to determine the speed of sound in air by producing stationary waves inside a horizontal glass tube.

Fine powder is sprinkled inside the tube. A loudspeaker is placed close to the open end of the tube. The other end of the tube is closed. The loudspeaker is connected to a signal generator producing a frequency of 2.72 kHz. The powder inside the tube forms piles at certain locations inside the tube, see **Fig. 16. 2**.

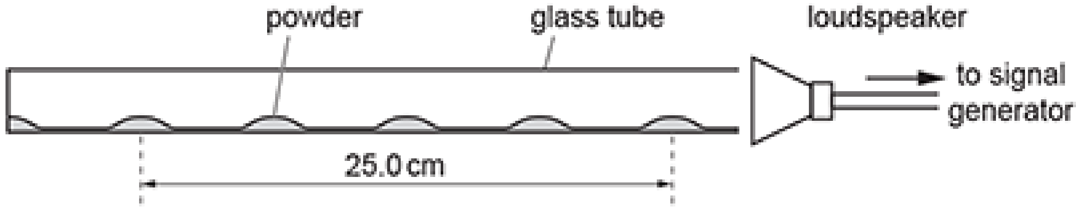


Fig. 16.2 (not to scale)

i. Suggest why the powder piles up at the nodes within the tube.

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[1]

ii. Use **Fig. 16. 2** to determine the speed of sound v.

v = ... ms^{-1} **[3]**

iii. Determine the fundamental (minimum) frequency f_0 of the stationary wave that can be formed within this tube.

f_0 = ... Hz **[2]**

4 State **one** difference and one similarity between the **oscillations** of a stationary sound wave and a progressive sound wave

Difference: ....

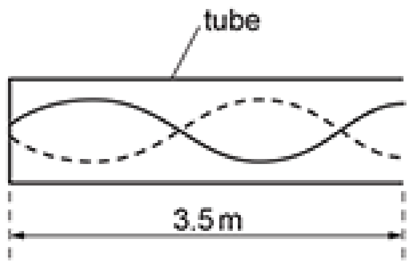
....

Similarity: ....

....

[2]

5 A stationary sound wave formed in a tube is shown below.



The tube is closed at one end. The length of the tube is 3.5 m.
The speed of sound is 340 m s^{-1}.

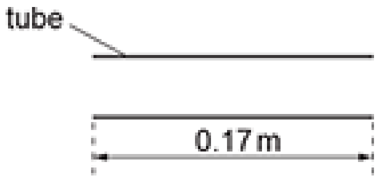
What is the frequency of the sound wave?

A 97 Hz
B 120 Hz
C 240 Hz
D 486 Hz

Your answer

[1]

6 A stationary sound wave, in its fundamental mode of vibration, is formed in a tube open at both ends.



The length of the tube is 0.17 m. The speed of sound in air is 340 m s^{-1}.

Which row for this stationary wave is correct?

	Number of nodes	Frequency of stationary wave / Hz
A	1	500
B	1	1000
C	2	1000
D	2	2000

Your answer [ ] **[1]**

7 This question is about a progressive wave and a stationary wave.

Which statement is correct?

A A progressive wave has at least one node.
B All progressive waves are longitudinal.
C All particles oscillating between two adjacent nodes in a stationary wave are in phase.
D The superposition of two waves travelling in the same direction produces a stationary wave.

Your answer [ ] **[1]**

8(a) Fig. 17.1 shows the variation with distance of the displacement of a **stationary** wave at time $t = 0$.

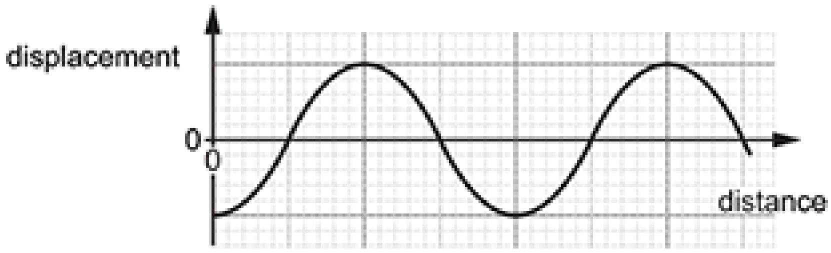


Fig. 17.1

The period of the wave is T.

i. On Fig. 17.1, sketch a graph to show the variation of the displacement at time $t = \frac{T}{2}$.

[1]

ii. On Fig. 17.1, show the positions of **all** the nodes. Label each node **N**.

[1]

(b) Stationary sound waves are formed in a tube closed at one end.

Fig. 17.2 shows three stationary wave patterns formed in the air column of the tube.

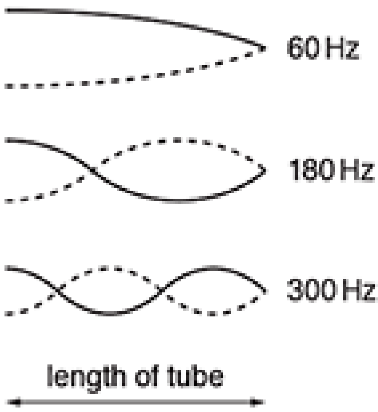


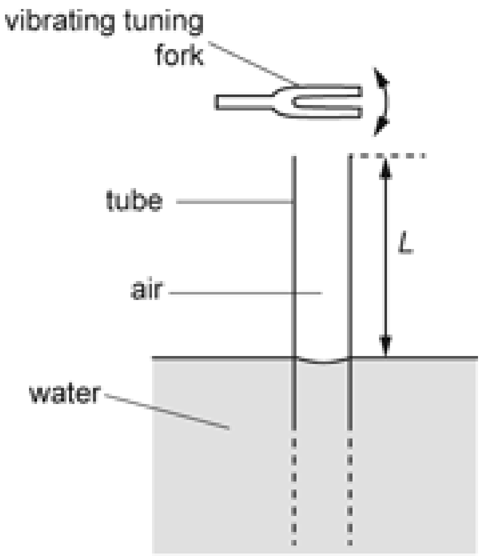
Fig. 17.2

The frequency *f* of the oscillations for each stationary wave is shown in Fig. 17.2.

Use Fig. 17.2 to explain how the frequency *f* of the sound wave depends on the wavelength λ.

[3]

9 A vibrating tuning fork is held above the open end of a long vertical tube. The other end of the tube, which is also open, is immersed in a tank of water. The length L of the air column within the tube is changed by raising or lowering the tube.



The wavelength of sound from the vibrating tuning fork is 150.0 cm.

What length L of air column will **not** produce a stationary wave within the tube?

A 37.5 cm
B 75.0 cm
C 112.5 cm
D 187.5 cm

Your answer [1]

10 Stationary waves are produced in a tube closed at one end and open at the other end. The fundamental frequency is 120 Hz.

What is a possible frequency of a harmonic for this tube?

A 60 Hz

B 240 Hz

C 360 Hz

D 480 Hz

Your answer [1]

11 *Fig. 18.2 shows an arrangement used to investigate **stationary** sound waves in a tube closed at one end.

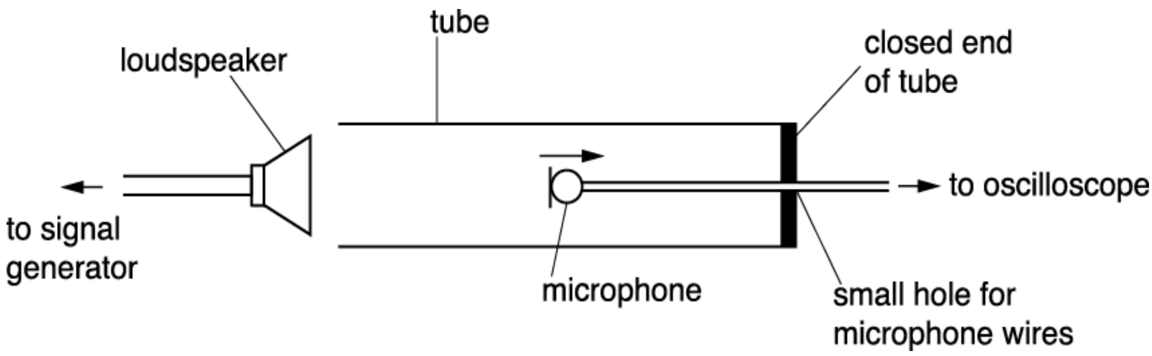


Fig. 18.2

A loudspeaker is placed at the open end of the tube. The loudspeaker emits sound of constant frequency.
A small microphone is placed inside the tube. The microphone is connected to an oscilloscope. The microphone is slowly moved from the open end of the tube towards its closed end. The signal detected by the microphone shows regions of maximum and minimum intensity of sound. The distance between adjacent positions of maximum signal is 0.26 m.

Fig. 18.3 shows the signal displayed on the oscilloscope when the output signal from the microphone is maximum. The time-base on the oscilloscope is set at 0.50 ms div^{-1}.

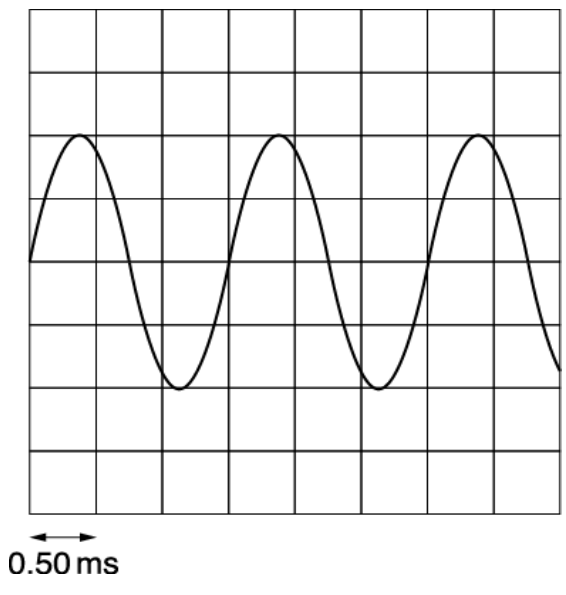


Fig. 18.3

Explain the presence of the regions of maximum and minimum intensities of sound within the tube and determine the speed of sound.

[6]

12 A student blows across the open end of an empty bottle.

Which diagram shows a possible stationary wave pattern for this bottle?

A 

B 

C 

D 

Your answer

[1]

13(a) A guitar manufacturer wants to investigate the quality of sound produced from a new uniform polymer string. **Fig. 18.1** shows the string which is kept in tension between a clamp and a pulley. The frequency of the mechanical oscillator close to one end is varied so that a stationary wave is set up on the string.

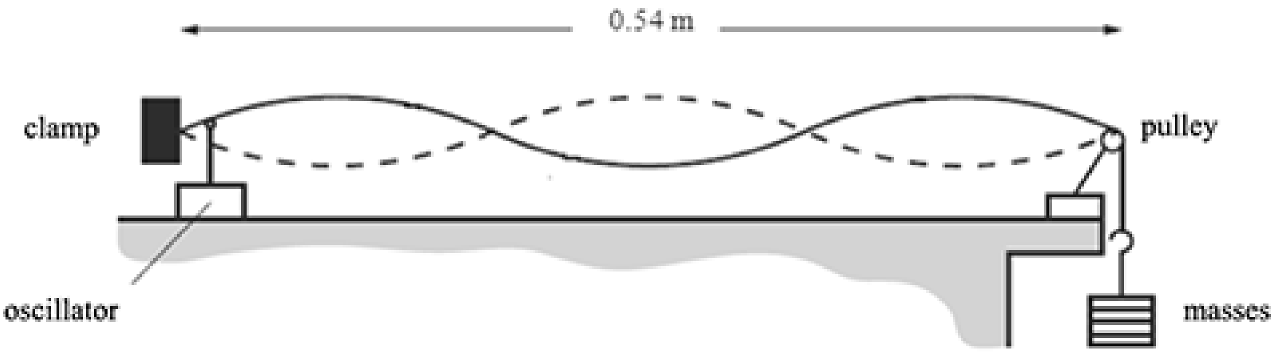


Fig. 18.1

Explain how the stationary wave is formed on this stretched string.

--- **[2]**

(b) The frequency of the oscillator is 60 Hz.

Use Fig. **18.1** to calculate the speed of the transverse waves on the string.

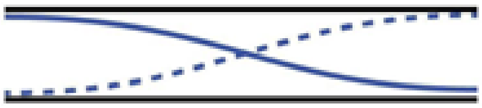
speed = ____________________ m s^{-1} **[3]**

(c) The speed v of the transverse waves on the string is directly proportional to $\sqrt{T}$, where T is the tension in the string.
The tension T in the string is increased by 14 %. The frequency f of the oscillator is adjusted to get the same stationary wave pattern as **Fig. 18.1**.

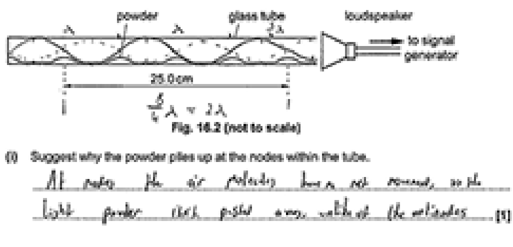
Calculate the percentage increase in the frequency f.

increase = ____________________ % **[2]**

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1	a			B1	Both parts needed – either dotted or solid. Correct curvature needed by eye. Middle node by eye. **IGNORE** lines outside of tube **<u>Examiner's Comments</u>** The majority of candidates were able to correctly identify and draw the fundamental mode in between the two given lines. Examiners were fairly generous on this; however the following would be penalised: not drawing the node in the centre, having the wrong curvature, and drawing straight lines. This is a relatively simple sketch, but candidates must take care. Some candidates attempted a longitudinal wave sketch and several others just drew a large number of waves, indicating they had not really appreciated the question. As always, it is recommended that candidates use pencil; those who made mistakes often drew another set of a parallel lines and then put in their answer. Examiners will always consider this; however it is better to use the original question image.
	b		Frequency f_0 = 340 / 0.600 = **567** (Hz)	A1	Correct to at least 2 significant figures No ecf from 18(a) **<u>Examiner's Comments</u>** Around two thirds of candidates were able to calculate this correctly. The majority of incorrect responses were naturally when using 0.30 m as the wavelength. Relatively few candidates did not change their wavelength into metres, but a significant number were unable to rearrange the formula correctly.

Question			Answer/Indicative content	Marks	Guidance
	c		Next wavelength for standing wave is λ = 0.300m Frequency = 340 / 0.300 = **1.13 x 10^3** (Hz)	C1 A1	Ecf from (b) if wavelength used is 0.600m Correct to at least 2 significant figures Special case: If wavelength drawn in (a) is 0.300m and f_0 in (b) = 1130 Hz, then allow ecf (C1) for next λ = 0.200m and (A1) frequency as 1700 Hz for full credit. <u>Examiner's Comments</u> Most candidates appreciated that the wavelength would be smaller (and many drew a sketch) to produce the next frequency. However, it was difficult to score marks on this if the previous answers were incorrect. Error carried forward is often applied, but in this case major errors will compound and it is not possible to work through the candidates thinking.
			Total	4	
2			D	1	<u>Examiner's Comments</u> Around one third of candidates were able to identify the correct response; the main difficulty appeared to be that the given angle in the glass was not given relative to the normal (as is usual) and this meant that a common distractor was **A**.
			Total	1	

Question			Answer/Indicative content	Marks	Guidance
3		i	Zero amplitude / displacement / oscillations / movement (at the nodes)	B1	**Allow** minimum or least for zero throughout **Ignore** references to pressure e.g. min/max pressure **Allow** correct answers in terms of pressure gradients **Penalise** incorrect answers in terms of antinodes **Ignore** correct answers in terms of antinodes Examiner's Comments Most candidates were able to appreciate that the stationary wave has nodes and antinodes and correctly relate them to the movement of the particles. Candidates were expected to give their responses in terms of the nodes, and responses in terms of the antinodes – such as powder is displaced from the antinodes – does not really answer the question. Several candidates drew a stationary wave on the diagram, with nodes and antinodes at the correct places. As the exemplar below shows, this helps confirm in the candidates mind the variation of the oscillations of the stationary wave. It also helps with subsequent questions; although cannot be given marks itself, candidates are always to be encouraged to make additions to diagrams to help them in supporting their responses.  A candidate drawing on the diagram to assist them to appreciate the vibrations at the nodes and antinodes.

Question			Answer/Indicative content	Marks	Guidance
		ii	$2\lambda = 25$ (cm) / $\lambda = 12.5$ (cm) $v = 2720 \times 0.125$ $v = 340$ (ms^{-1})	C1 C1 A1	**Maximum** one POT error in this question **Special case: one mark only** for bare 340 (ms^{-1}) with no working **Allow** 2 marks for 170 ms^{-1} if calculated from $\lambda = 6.25$ (cm) Examiner's Comments This question was well answered by most candidates who were able to correctly appreciate that the given distance of 25cm corresponded to two complete wavelengths of the stationary wave. Encouragingly, very few candidates did not make the cm to m conversion. A small number of candidates thought that the wavelength was the distance between two nodes resulting in an answer of 170 ms^{-1}. Many candidates structured their responses clearly and were able to explain their reasoning.
		iii	$11f_0 = 2.72$ ($\times10^3$) or $11/4 \times 12.5 = \lambda_o/4$ **or** $\lambda_o = 1.375$ (m) $f_0 = (340 / 1.375) = 247$ (Hz)	C1 A1	**Allow** length of tube = 0.344 (m) **Allow** 250 (Hz) **Allow** ecf on v from (c)(ii). Examiner's Comments This proved to be a challenging question and only around one fifth of the candidates were able to score any marks. Most successful candidates appreciated that there were 11 quarter wavelengths of the initial wave in the tube and used this to determine the length of the tube, from which they were able to determine the fundamental wavelength and hence the frequency. There are many potential errors in this question, however a common incorrect response was 680Hz, calculated from treating the wavelength of the fundamental wave as twice the given distance of 25cm.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
4			Difference: (stationary waves) has nodes / antinodes Similarity: Oscillations are longitudinal	B1 B1	Differences and/or similarities can be described in terms of net energy transfer, phase or amplitude variations <u>Examiner's Comments</u> This question is clear that the differences and similarities should be based on the oscillations. Few candidates did this, but other routes could be used to gain credit. Candidates should be careful not to create lists in this style of question and simply produce a single response, as contradictions can be penalised.
			Total	2	
5			B	1	<u>Examiner's Comments</u> The correct response is **B**. Around two thirds of candidates were able to correctly calculate the frequency; this question relies on the candidate appreciating that there is more than one complete cycle in the tube and then evaluating the correct wavelength. It is then a straightforward calculation. As expected, most of the incorrect responses were **A**, where the wave equation had simply been used with the given numbers. Several candidates drew on the diagram to help in their calculation of the wavelength, although some thought that the wavelength was two thirds of the tube length, rather than four fifths.
			Total	1	
6			B	1	
			Total	1	
7			C	1	
			Total	1	

Question			Answer/Indicative content	Marks	Guidance
8	a	i	'Inverted' graph	B1	**Ignore** amplitude Examiner's Comments The majority of the candidates drew the correct variation of the displacement after a time of half a period. In **(a)(ii)**, it was good to see the nodes clearly marked with the letters **N**. The most common mistake was to draw a curve with a different period with nodes at all the points where the displacement was zero.
		ii	Nodes shown correctly	B1	Expect at least 2 nodes labelled **N** No mark if the labels **N** are omitted **Note** the nodes must be on the original graph and not that sketched in **(a)(i)**

Question			Answer/Indicative content	Marks	Guidance
	b		Correct relationship between length of tube and λ for at least **two** stationary waves	B1	**Allow** L for length of tube Example $L = \lambda/4$ at 60 Hz, $L = 3\lambda/4$ at 180 Hz $L = 5\lambda/4$ at 300 Hz **Allow** $\lambda/4$ linked to 60 (Hz) etc on diagram or in text
			speed / v is constant **or** $f\lambda$ = constant **or** f $\infty 1/\lambda$	B1	**Not** just f increases λ decreases
			Calculation comparing at least **two** stationary waves to show $f\lambda$ = constant **or** $f \infty 1/\lambda$	B1	**Note** - calculation can also score the previous B1 mark E.g f increases by a factor of 5 (from 60 Hz to 300 Hz) and λ decreases by the same factor (of 5) <u>Examiner's Comments</u> The majority of the candidates scored 1 mark for either mentioning that the wavelength was *inversely proportional to the frequency* or identifying the correct relationship between the length of the tube and the wavelength. Generally, the explanations lacked cohesion and showed poor comprehension of stationary waves formed within a fixed column of air. The common errors are highlighted below. ? **Misconception** There were some missed opportunities, with some candidates making the following mistakes. • **wavelength** = $\lambda/4$, $3\lambda/4$ and $5\lambda/4$, instead of **length of tube** = $\lambda/4$, $3\lambda/4$ and $5\lambda/4$. • Correctly identifying the relationship between L and λ, but then confusing L and λ, and stating that the $f \propto \lambda$. • Using an equal sign instead of the proportionality symbol, e.g. *frequency is inversely proportional wavelength, hence* $f = 1/\lambda$.
			Total	**5**	
9			**B**	1	

Question			Answer/Indicative content	Marks	Guidance
			Total	1	
10			C	1	
			Total	1	

Question			Answer/Indicative content	Marks	Guidance
11			***Level 3 (5–6 marks)** Clear explanation and analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some explanation and some analysis. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited explanation **or** limited analysis *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	B1 × 6	**Indicative scientific points may include:** **Explanation** • Sound reflected at closed end • Superposition / interference produces stationary wave within tube • Maximum identified as anti-nodes • Minima identified as nodes **Analysis** • $\lambda/2 = 0.26$ (m) or $\lambda = 0.52$ (m) • period = 1.5 (ms) • frequency = 1/0.0015 or frequency = 660 (Hz) • $v = 0.52 \times 660 = 340$ m s^{-1} (**Note**: $v = 350$ m s^{-1} if there is no rounding.)
			Total	**6**	
12			C	1	
			Total	**1**	

Question			Answer/Indicative content	Marks	Guidance
13	a		Waves are reflected at the pulley end. This produces nodes and antinodes on the string.	B1 B1	
	b		$\lambda / 2 = 0.54 / 3 = 0.18$ m $\lambda = 0.18 \times 2 = 0.36$ (m) $v = 60 \times 0.36$; speed = 21.6 m $s^{-1} \approx 22$ (m s^{-1})	C1 C1 A1	
	c		$v \propto f$ and since $v \propto \surd T$, therefore $f \propto \surd T$ frequency will increase by a factor of $\surd 1.14 = 1.068$, therefore increase = 6.8%	C1 A1	
			Total	**7**	