Mark Scheme

Q1.

Question Number	Answer	Mark
	C is the correct answer as the distance between adjacent nodes is half a wavelength A is not the correct answer as all points between two adjacent nodes are in phase. B is not the correct answer as antinodes are points of maximum amplitude. D is not the correct answer as stationary waves have no net transfer of energy.	**(1)**

Q2.

Question Number	Answer	Mark
	D is the correct answer as X and Z are in two adjacent node to node sections, which will always be in antiphase with each other A is not the correct answer as W and X are between the same pair of nodes, between which all points are in phase B is not the correct answer as W and Y are in two adjacent node to node sections, which will always be in antiphase with each other C is not the correct answer as X and Y are in two adjacent node to node sections, which will always be in antiphase with each other	**(1)**

Q3.

Question Number	Answer	Mark
	C is the correct answer A is not the correct answer as these would be in antiphase B is not the correct answer as these would be in antiphase D is not the correct answer as this is incorrect	**1**

Q4.

Question Number	Answer	Mark
	The only correct answer is B – phase difference between P and Q is 0° and amplitude of oscillation of P and Q is less than *A* **A** is not correct because the amplitude of oscillation of P and Q is less than *A* **C** is not correct because P and Q are in phase and the amplitude of oscillation of P and Q is less than *A* **D** is not correct because P and Q are in phase	1

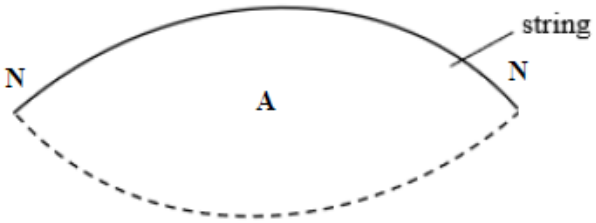
Q5.

Question Number	Answer	Mark
	The only correct answer is B - **A** is not correct because this pattern would form after the waves move a quarter of a wavelength. **C** is not correct because the waves would completely destructively interfere after moving three quarters of a wavelength. **D** is not correct because this pattern would form after the waves move 1 wavelength.	1

Q6.

Question Number	Answer		Mark
(a)(i)	Recognises that wavelength = 2 × length of recorder **Or** recognises that length of recorder = $\lambda/2$ **Or** see that λ used is 47.2 cm / 0.472 m	(1)	
	Use of $v = f\lambda$ with $v = 330\ \text{m s}^{-1}$	(1)	
	$f = 700$ Hz	(1)	3
	<u>Example of calculation</u> Wavelength = 2 × length of recorder = 2 × 0.236 m = 0.472m $v = f\lambda$ so $f = 330\ \text{m s}^{-1} / 0.472\ \text{m} = 699$ Hz		
(a)(ii)	To keep same frequency, wavelength would need to increase	(1)	
	So length of recorder needs to increase **Or** so length of air column needs to increase	(1)	
	This is achieved by sliding the recorder sections further apart **Or** this is achieved by loosening the sections of the recorder	(1)	3
	(Do not award MP2 or MP3 if clearly linked to a decrease in wavelength)		
(b)	See $v = f\lambda$ and $v = \sqrt{(T/\mu)}$	(1)	
	Combines equations to show that $f \propto \sqrt{T}$ **or** $T = kf^2$ **Or** recognises that $T_2/T_1 = (f_2/f_1)^2$ **Or** see $\frac{(440)^2-(432)^2}{(432)^2}$	(1)	
	Percentage increase in T is 3.7%	(1)	3
	<u>Example of calculation</u> $f\lambda = \sqrt{(T/\mu)}$ so $T = kf^2$ $T_2/T_1 = (f_2/f_1)^2$ so $T_2/T_1 = (440\ \text{Hz}/432\ \text{Hz})^2 = 1.037$ Percentage increase in T is 3.7%		
	Total for Question		**9**

Q7.

Question Number	Answer	Mark
(a)	Nodes labelled at both ends **and** Antinode labelled in the middle of the string (1)  	1
(b)	Waves / vibrations <u>reflect</u> (1) from the end(s) of the string (1) superposition / interference occurs (1)	3
(c)(i)	Equates $f\lambda$ with $\sqrt{\frac{T}{\mu}}$ (1) Equates λ to 2l (1) $f^2 = \frac{1}{4l^2\mu} \cdot T$ compares with $y = mx\ (+c)$ (1)	3
(c)(ii)	Determines $\frac{\Delta f^2}{\Delta T}$ (1) Uses gradient $= \frac{1}{4l^2\mu}$ (1) $\mu = 6.4 \times 10^{-4}$ kg m^{-1} to 6.7×10^{-4} kg m^{-1} (1) <u>Example calculation</u> Gradient $= \frac{2500}{4.7} = 532$ $532\ \text{Hz}^2\ \text{N}^{-1} = \frac{1}{4 \times (0.85\ \text{m})^2 \times \mu}$ $\mu = \frac{1}{4 \times (0.85\ \text{m})^2 \times 532\ \text{Hz}^2\ \text{N}^{-1}} = 6.50 \times 10^{-4}$ kg m^{-1}	3
	Total for question	**10**

Q8.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*(a)</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Indicative content

IC1 Vibrating tuning fork produces (sound) waves (in air)
IC2 The (sound) wave (travels down the tube and) reflects from the (closed) end
IC3 Reflected wave superposes / interferes with incident waves
IC4 Constructive interference / superposition where waves are in phase
Or
Destructive interference / superposition where waves are in antiphase
IC5 Maximum amplitudes producing antinodes
Or
Zero amplitude producing nodes
IC6 There must be an antinode at the open end
Or
There is a node at the closed end</td><td>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative points seen in answer</th><th>Number of marks awarded for indicative points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
<table>
<tr><th></th><th>Number of marks awarded for structure and lines of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table></td><td>6</td></tr>
</table>

(b)(i)	Use of $v = f\lambda$ **(1)** With $\lambda = 4 \times$ length of column (or see 0.816 m) **(1)** $f = 417$ Hz **(1)**	<u>Example of calculation</u> $\lambda = 4 \times 0.204\ \text{m} = 0.816\ \text{m}$ $f = \frac{v}{\lambda} = \frac{340\ \text{m s}^{-1}}{0.816\ \text{m}} = 417\ \text{Hz}$	**3**

b(ii)	The antinode is not exactly at the open end of the tube **(1)** **Or** There is an end correction at the open end of the tube So the (actual) wavelength would be longer (than the measured / calculated wavelength) **(1)**		**2**

Q9.

Question Number	Answer		Mark
(a)	Uses at least 3 waves to determine T	(1)	
	Use of $f = 1/T$	(1)	
	f = in range 375 to 425 Hz	(1)	3
	<u>Example of calculation</u> $T = \frac{5 \times 1.5 \times 10^{-3}\ \text{s}}{3} = 2.5 \times 10^{-3}\ \text{s}$ $f = \frac{1}{2.5 \times 10^{-3}\ \text{s}} = 400\ \text{Hz}$		
(b)	Wavelength of wave 1 is three times the wavelength of wave 2 **or** Wavelength of 4λ seen for wave 1 and $\frac{4}{3}\lambda$ seen for wave 2	(1)	
	So frequency of wave 1 is a third the frequency of wave 2	(1)	
	Because the speed of sound is constant and $v = f\lambda$	(1)	3
(c)	Draws line of best fit and calculates gradient	(1)	
	v = in the range 320 *to* 345 m s^{-1}	(1)	2
	<u>Example of calculation</u> $v = \frac{0.48\ \text{m} - 0.33\ \text{m}}{1.5 \times 10^{-3}\text{Hz}^{-1} - 1.05 \times 10^{-3}\text{Hz}^{-1}} = 333\ \text{m s}^{-1}$		
(d)	Use of $v = f\lambda$	(1)	
	Use of $\lambda = 4 \times L$	(1)	
	f = 300 Hz	(1)	3
	<u>Example of calculation</u> $\lambda = 4 \times 0.282\ \text{m} = 1.13\ \text{m}$ $f = \frac{340\ \text{m s}^{-1}}{1.13\ \text{m}} = 301\ \text{Hz}$		
	Total for question		**11**

Q10.

Question Number	Answer	Mark
ai	Divides 2Hz by 880 or 881Hz or 882Hz (1) 0.23% / 0.2% is less than 0.3% (so heard as same frequency) (1) **OR** Calculates 0.3% of 880 Hz or 882Hz (1) 879.4 Hz is less than 880 Hz (so heard as same frequency) **Or** 882.6 Hz is greater than 882 Hz (so heard as same frequency) **Or** 2.6 Hz is greater than 2 Hz (so heard as the same frequency) (1) <u>Example of calculation</u> $\frac{(882-880)\text{ Hz}}{882\text{ Hz}} \times 100 = 0.23\%$	2

*	aii	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

	Indicative content • The two sound waves are not coherent (as they have a different frequency) • As they do not have a constant phase relationship/difference **Or** the phase difference changes • Loud sounds related to constructive interference/superposition • Quiet sounds related to destructive interference/superposition • Constructive/loud sounds when in phase • Destructive/quiet sounds when out of phase (IC5 – allow phase difference of $2n\pi$ radians / 0°) (IC6 – allow antiphase or phase difference of π radians / 180°) (Do not accept answers in terms of path differences or λ)	**6**

b	Use of $v = f\lambda$ (1) $\lambda = 2L$ used (1) Use of $v = \sqrt{(\frac{T}{\mu})}$ (1) Decrease in tension = 2.5 N (1) <u>Example of calculation</u> $(f\lambda)^2 = T/\mu$ $\lambda = 2L = 2 \times 0.187 = 0.374$ m for 882 Hz, $(882 \text{ Hz} \times 0.374 \text{ m})^2 = T / 5.08 \times 10^{-3} \text{ kg m}^{-1}$ $T = 552.8$ N for 880 Hz, $(880 \text{ Hz} \times 0.374 \text{ m})^2 = T / 5.08 \times 10^{-3} \text{ kg m}^{-1}$ $T = 550.3$ N decrease in $T = 2.5$ N	**4**
	Total for question	**12**

Q11.

Question Number	Answer		Mark
a	(Two) waves travelling in opposite directions **Or** wave meeting its reflection	(1)	
	Nodes are points of zero/minimum amplitude **and** antinodes are points of maximum amplitude	(1)	
	Nodes linked to destructive interference **and** antinodes linked to constructive interference	(1)	3
b	Equates $v = f\lambda$ and $v = \sqrt{(T/\mu)}$	(1)	
	Rearranges to give $f^2 = \frac{T}{\mu\lambda^2}$ **Or** $f^2 = \frac{T}{\mu(2L)^2}$	(1)	
	Replaces T with W in equation	(1)	
	Where μ and λ are constants **Or** where μ and L are constants	(1)	
	$f^2 \propto W$ **Or** no "c" in "$y=mx+c$" **Or** y-intercept is 0 **Or** in the format $y = mx$	(1)	5
	(MP5 is dependent on some correct working leading to an equation) (Award MP4 if stated that $\frac{1}{\mu\lambda^2}$ = constant or equivalent in terms of l)		
c	(Connect signal generator to) cathode ray oscilloscope **Or** record movement of the string with a video camera	(1)	
	(Measure time period T and) calculate $f = 1/T$	(1)	2
d	Use of $v = \sqrt{(T/\mu)}$	(1)	
	Identifies that $\lambda = 2L$	(1)	
	$\mu = 4.3 \times 10^{-4}$ kg m^{-1}	(1)	3
	<u>Example of calculation</u> $f\lambda = \sqrt{(T/\mu)}$, 659 Hz × (2 × 0.328 m) = $\sqrt{(80.0\ \text{N} / \mu)}$, $\mu = 4.3 \times 10^{-4}$ kg m^{-1}		
	Total for question		**13**

Q12.

Question Number	Answer		Mark
(a)	Wave (on string) is reflected	(1)	
	At the end/peg/bridge	(1)	
	Superposition/interference takes place	(1)	3
(b)	Use of $v = \sqrt{\frac{T}{\mu}}$	(1)	
	Use of $v = f\lambda$	(1)	
	And $\lambda = 2L$	(1)	
	f = 293 (Hz, which is closest to) String 2	(1)	4
	Example of calculation $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{71.5\ \text{N}}{2.03 \times 10^{-3}\ \text{kg m}^{-1}}} = 187.7\ \text{m s}^{-1}$ $v = f\lambda$, so f = 187.7 m s^{-1} / (2 × 0.32 m) = 293 Hz		
(c)	Waves have the same frequency/period	(1)	
	Waves have different speeds/wavelengths	(1)	
	Sound wave has same amplitude for all points **and** stationary wave does not	(1)	
	Sound waves transfer energy **and** stationary waves do not	(1)	
	Waves on string are transverse **and** sound waves are longitudinal	(1)	5
	(MP2 – do not allow contradictions e.g. "they have different speeds but the same wavelength")		
	Total for question		**12**

Q13.

Question Number	Answer		Mark
a	Wave reflected at the pulley Superposition/interference (takes place)	(1) (1) (1)	3
b	Use of $W = mg$ Use of $v = \sqrt{(T/\mu)}$ Use of $v = f\lambda$ to find λ $\lambda = 1.2$ (m) node to node distance = $\lambda/2$, so there is a node at R **Or** See $\lambda/2 = 0.6$m, so there is a node at R (MP4 requires evidence of calculation) Example of calculation Tension in string = $W = mg$ = (0.300 kg) (9.81 N kg^{-1}) = 2.94N $v = \sqrt{(T/\mu)} = \sqrt{\frac{2.94\text{ N}}{2.27 \times 10^{-3}\text{ kg m}^{-1}}} = 36.0\text{ m s}^{-1}$ $\lambda = \frac{v}{f} = \frac{(36.0\text{ m s}^{-1})}{(30\text{ Hz})} = 1.20$ m node to node distance = $\lambda/2$, so node to node distance = 0.60 m.	(1) (1) (1) (1) (1)	5
ci	S and T are in antiphase **Or** 180° out of phase **Or** π radians out of phase S and T are in adjacent node-to-node regions **Or** S and T are in adjacent loops	(1) (1)	2
cii	S has a greater amplitude than T S is at an antinode **and** T is between a node and antinode **Or** S is at an antinode **and** T is not **Or** T is closer to a node than S (MP2 dependent on MP1)	(1) (1)	2
	Total for question		**12**

Q14.

Question Number	Answer		Mark
(a)	Oscillations / waves <u>reflect</u> from (each) end of the cable	(1)	
	The (reflected) waves interfere / superpose	(1)	
	A node forms where there is destructive interference **Or** An antinode forms where there is constructive interference	(1)	3
(b)	Point X has a large / maximum amplitude	(1)	
	At point X the displacement varies (between maximum displacement and zero displacement)	(1)	
	At point Y the cable always has zero displacement **Or** At point Y the cable is stationary	(1)	3

(c)(i)	Calculates mass per unit length	(1)	
	$\mu = 24.1$ (kg m^{-1})	(1)	2
	<u>Example calculation</u> $\mu = \frac{2.10 \times 10^3 \text{ kg}}{87.0 \text{ m}}$ $\mu = 24.14$ kg m^{-1}		
(c)(ii)	Use of $W = mg$	(1)	
	Use of $T = \frac{W}{\text{number of cables}}$	(1)	
	Use of $v = \sqrt{\frac{T}{\mu}}$	(1)	
	Use of $v = f\lambda$ with $\lambda = 320$ m **or** $\lambda = 7$ m **Or** Use of $v = f\lambda$ with $f = 280$ Hz	(1)	
	Lowest possible frequency produced by standing wave on longest cable = 1.1 Hz **Or** Lowest possible frequency produced by standing wave on shortest cable = 48 Hz **Or** Length of cable needed to give lowest frequency of 280 Hz = 0.60 m	(1)	
	Lowest frequency waves produced < 280 Hz so humming is not produced by standing waves on the suspending cables **Or** length of cable is not within range 3.5 to 160 m so humming is not produced by standing waves on the suspending cables	(1)	6
	<u>Example calculation</u> $W = 140 \times 10^6 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 1.37 \times 10^9 \text{ N}$ $T = \frac{1.37 \times 10^9 \text{N}}{500} = 2.74 \times 10^6 \text{ N}$ $v = \sqrt{\frac{2.74 \times 10^6 \text{ N}}{24 \text{ kg m}^{-1}}} = 338 \text{ m s}^{-1}$ $f = \frac{338 \text{ m s}^{-1}}{320} = 1.06$ Hz **or** $f = \frac{338 \text{ m s}^{-1}}{7} = 48.3$ Hz Lowest frequency waves produced < 280 Hz so humming is not produced by standing waves on the suspending cables		
	Total for question		**14**