Mark Scheme

Q1.

Question Number	Answer	Mark
	A is the correct answer B is not the correct answer as it can be altered to change frequency (CP 5) C is not the correct answer as it can be altered to change frequency (CP 5) D is not the correct answer as it can be altered to change frequency (CP 5)	(1)

Q2.

Question Number	Answer	Mark
	The only correct answer is B $\left(\sqrt{\frac{20 \times 2.5}{0.005}}\right)$ A is not correct because this does not include mass C is not correct because this is tension x mass per unit length D is not correct because has no length included	1

Q3.

Question Number	Answer	Mark
	The only correct answer is A (decreasing the length *l*) B is not correct because lower tension would decrease the frequency C is not correct as strings with greater diameter vibrate with lower frequency D is not correct as strings with greater mass per unit length vibrate with lower frequency	1

Q4.

Question Number	Answer	Mark
	C is the correct answer A is not the correct answer as $T = \mu v^2$ or $T \propto {}^{m}/_{l}$ so $2l$ is $T/2$ B is not the correct answer as $T = \mu v^2$ or $T \propto {}^{m}/_{l}$ so $2l$ is $T/2$ D is not the correct answer as $T = \mu v^2$ or $T \propto {}^{m}/_{l}$ so $2l$ is $T/2$	**1**

Q5.

Question Number	Answer	Mark
	A is the correct answer as $v = \sqrt{(T/\mu)}$, where $T = Mg$ and μ = mass m per unit length, where length = $4L/3$ B is not the correct answer as this suggests the overall length of the string is $2L/3$ C is not the correct answer as this suggests the overall length of the string is L D is not the correct answer as this suggests the overall length of the string is $L/3$	**(1)**

Q6.

Question Number	Answer	Mark
	D is the correct answer as $v = \sqrt{(T/\mu)}$ and increasing T increases v A is not the correct answer as this would only alter the wavelength of the wave B is not the correct answer as this does not affect the speed of the wave C is not the correct answer as this would decrease the speed of the wave	**(1)**

Q7.

Question Number	Answer	Mark
	The only correct answer is B $(\sqrt{2} \times f)$ A is not correct because this would be the value of tension was halved C is not correct because this would be the value if the tension were reduced by a factor 4 D is not correct because this would be the value if the tension were increased by a factor 4	**1**

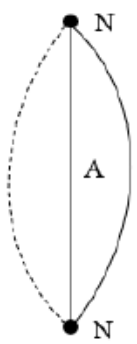
Q8.

Question Number	Answer	Mark
	C is the correct answer A is not correct because mass per unit length should not change so the denominator should be 1 B is not correct because mass per unit length should not change so the denominator should be 1 D is not correct because velocity should be proportional to the square root of tension	**1**

Q9.

Question Number	Answer	Mark
a	Recognises that node to node distance = $\lambda/2$ **Or** $\lambda = L/2$ stated (1) Wavelength = 0.85m (1) <u>Example of calculation</u> Node to node distance = $\lambda/2$. String has 4 loops so total length of string is 2λ λ = 1.70 m / 2 = 0.85 m.	(2)
b	Use of $v = \sqrt{(T/\mu)}$ (1) Use of $T = mg$ (1) $v = 21\ \text{m s}^{-1}$ (1) <u>Example of calculation</u> $T = mg = 0.20\ \text{kg} \times 9.81\ \text{N kg}^{-1} = 1.96\ \text{N}$ $v = \sqrt{(T/\mu)} = \sqrt{(1.96\ \text{N} / 4.5 \times 10^{-3}\ \text{kg m}^{-1})} = 20.9\ \text{m s}^{-1}$	(3)
c	T and μ are the same **Or** (As f decreases,) λ *in*creases (1) Speed would be the same **Or** There is no effect (on the speed) (1)	(2)

Q10.

Question Number	Answer	Mark
(a)	Oscillations / vibrations are perpendicular to the <u>direction</u> of energy transfer **Or** Oscillations / vibrations are perpendicular to the <u>direction</u> of wave travel (allow propagation for wave travel) (1)	1
(b)	Shape of wave correct (1) Node labelled at each end and antinode labelled in the middle (MP2 dependent on MP1) (1) <u>Example of diagram</u>  	2

(c)	Use of $v = f\lambda$	(1)	
	Use of $v = \sqrt{\frac{T}{\mu}}$	(1)	
	Use of $\mu = \frac{m}{l}$ [with l = 1.5 m]	(1)	
	Mass of string = 3.1 (g), so string B	(1)	4
	[Allow reverse working for full marks]		
	<u>Example of calculation</u> $v = 196\ \text{Hz} \times 0.72\ \text{m} = 141\ \text{m s}^{-1}$		
	$\mu = \frac{41\ \text{N}}{(141\ \text{m s}^{-1})^2} = 2.06 \times 10^{-3}\ \text{kg m}^{-1}$		
	$\text{m} = 1.5\ \text{m} \times 2.06 \times 10^{-3}\ \text{kg m}^{-1} = 3.09 \times 10^{-3}\ \text{kg}$		
	Total for question		**7**

Q11.

Question Number	Answer		Mark
a	Difficult to judge/measure the exact position of node **Or** Ruler is not close to the string (so there might be parallax error)	(1)	1
bi	Calculates gradient by best fit or plotted points from graph	(1)	
	Recognises distance between adjacent nodes = $\lambda/2$ **Or** Recognises that speed of waves on the string = 2 × gradient	(1)	
	Use of $v = \sqrt{\frac{T}{\mu}}$ to find T	(1)	
	Use of $T = mg$ with $g = 9.81\ \text{Nkg}^{-1}$ (accept $W = mg$)	(1)	
	m = 0.21 kg	(1)	5
	<u>Example of calculation</u> Gradient = $\frac{2.7\ m}{0.080\ s} = 33.75\ \text{ms}^{-1}$ Speed = 2 × gradient = $67.5\ \text{ms}^{-1}$ $v = \sqrt{T/\mu}$, $67.5\ \text{m s}^{-1} = \sqrt{\frac{T}{4.5 \times 10^{-4}\ \text{kg m}^{-1}}}$ $T = 2.05$ N $m = \frac{W}{g} = \frac{T}{g} = \frac{2.05\text{N}}{9.81\ \text{Nkg}^{-1}} = 0.209$ kg		
bii	Straight line with shallower gradient drawn, starting from origin Line has a gradient of around 0.7 × line drawn (Graph line if continued to the last value for $1/f$ should be between 1.8 and 2.0m for d).	(1) (1)	2
	Total for question		8

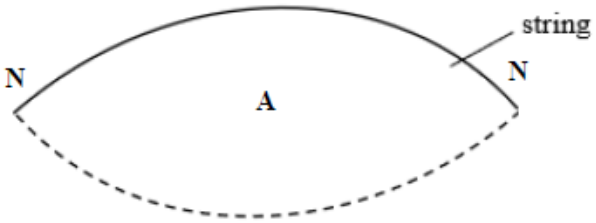
Q12.

Question Number	Answer		Mark
a	(Two) waves travelling in opposite directions **Or** Wave reflected back on itself	(1)	
	Superposition / interference occurs	(1)	**(2)**
bi	Units of u are ms^{-1} and units of d are m	(1)	
	Units of f are s^{-1}	(1)	**(2)**
bii	Use of $v = \sqrt{(T/\mu)}$	(1)	
	Recognises that $\lambda = 2L/3$ **Or** states that $\lambda = 0.22$ m	(1)	
	Uses their <u>calculated</u> v and their λ in $v = f\lambda$ to establish f	(1)	
	Use of $f = Ku/d$ with their f to establish u	(1)	
	$u = 1.1\ ms^{-1}$	(1)	**(5)**
	<u>Example of calculation</u> $v = \sqrt{(T/\mu)} = \sqrt{(63N / 0.58 \times 10^{-3}\ kgm^{-1})} = 330\ ms^{-1}$ $\lambda = 2L/3 = (2 \times 0.33 / 3) = 0.22$ m $f = v/\lambda = 330\ ms^{-1} / 0.22\ m = 1500$ Hz $u = fd/K = [1500\ Hz \times (0.15 \times 10^{-3}\ m)] / 0.2 = 1.125\ ms^{-1}$		
	Total for question		**9**

Q13.

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**

Q14.

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

Q15.

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**

Q16.

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 $v = f\lambda$ $\lambda = 2L$ used Use of $v = \sqrt{(\frac{T}{\mu})}$ Decrease in tension = 2.5 N <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	(1) (1) (1) (1)	**4**
	Total for question		**12**

Q17.

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**

Q18.

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**

Q19.

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**