PRESTON MANOR

Physics Exam Pack

Standing Waves

Name:

Date:

Question / Paper	Mark

....

....

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....

....

....[6]

(ii) Suggest how the appearance of the interference pattern changes when white light is used instead of monochromatic light.

....

....

....

....[2]

[Total: 13]

5 Fig. 5.1 shows a string stretched between two points **P** and **Q**.

Fig. 5.1

(a) Suggest how a standing wave could be created on the string.

....

....[1]

Turn over for question 5 (b) and (c)

(b) **(i)** Draw on Fig. 5.2 the shape of the standing wave when the string vibrates in its fundamental mode, i.e. the lowest frequency.

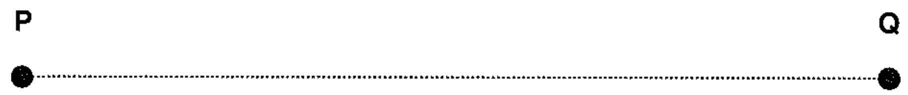


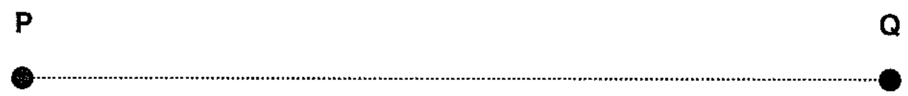
Fig. 5.2

....[1]

(ii) The distance between **P** and **Q** is 1.2 m. Calculate the wavelength of this standing wave.

wavelength = ... m [1]

(c) Draw on Fig. 5.3 the shape of a standing wave whose frequency is 3 times that of the fundamental frequency. Label the position of all nodes (N) and antinodes (A).



[3]

Fig. 5.3

[Total: 6]

END OF QUESTION PAPER

Question			Expected Answers	Marks	Additional Guidance
5	a		pluck/stroke/disturb/vibrate/twang string	B1	Allow this mark for oscillating P or Q
	b	i	correct diagram of fundamental i.e one loop	B1	Either full envelope or instantaneous pattern scores mark. Ignore any labelling of nodes and antinodes
		ii	wavelength = 2x1.2 = **2.4** m	B1	Allow ecf for candidates diagram
	c		Correct standing wave drawn i.e 3 'loops' All correct nodes labelled N for candidates diagram All correct antinodes labelled A for candidates diagram	B1 B1 B1	Either full envelope or instantaneous pattern scores mark Allow lack of Ns labelled at P and Q if the others are correct. If all A and N are exactly reversed then award one of these two marks.
			Total	**6**	

3 **(a)** With reference to the vibrations involved, state the difference between *transverse* and *longitudinal* waves. State an example of each.

....

....

....

example of a transverse wave: ....

example of a longitudinal wave: ....[3]

(b) State one similarity and one difference between *progressive* waves and *standing (stationary)* waves.

similarity: ....

....

difference: ....

....[2]

(c) Explain what is meant by

(i) a *node*

....

....[1]

(ii) an *antinode.*

....

....[1]

(d) The distance between a node and the neighbouring antinode in a standing wave formed on a stretched string is 0.12 m. Calculate the wavelength.

wavelength = ... m [1]

(e) Describe and explain how a standing wave can be formed using a suitable source of longitudinal waves. State the wave source and describe the arrangement using a labelled diagram. Label the position of a node (label as **N**) and an antinode (label as **A**).

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....

....[4]

[Total: 12]

2(a) ALL correct 3 marks – minus 1 for each error – stopping at ZERO B3 [3]

Definition	Symbol
number of cycles produced per unit time	F
maximum displacement	A
minimum distance between points on the wave moving in phase.	λ
distance travelled by the wave per unit time	V
Time taken for a complete one wave cycle	T

(b) (i) period = $1/f$ = 1/125 = 0.008 s *{allow 8ms, but 8 scores zero}* B1 [1]

(ii) smooth & <u>consistent wave drawn</u> (judged by eye) (ANY SHAPE!) B1
{i.e consistent amplitude and period and must start at origin}
amplitude correctly shown: 3 mm above AND 3 mm below time axis B1
correct period shown on graph {allow ecf from (i)} B1 [3]

(iii) correct phase difference shown (: e.g. x=3 (or -3) when t= 0) B1
same shape, amplitude and period as original wave B1 [2]
{generously judged by eye}
{If graphs are not labelled assume graph A is the one through the origin}

(iv) correct substitution into $v=f\lambda$: e.g. 340 = 125λ C1
λ = 340/125 = **2.72** m A1 [2]

QUESTION TOTAL = **11**

3(a) transverse waves: vibrations 90° to wave direction (WTTE) **AND**
longitudinal waves: vibrations parallel to wave direction (WTTE) B1
example of transverse waves: e.g light B1
example of longitudinal waves: e.g sound B1 [3]

(b) ***similarity***: anything valid: e.g. both have wavelength/frequency/vibrations B1
difference: anything valid: e.g. B1 [2]
no transfer of energy in standing waves
standing waves have nodes (&/or antinodes)
neighbouring pts vibrate in phase in standing waves but have a phase diff. in progressive

(c) (i) node = point of no movement/zero displacement (allow amplitude) B1
(ii) antinode = point of maximum movement/max displacement (amplitude) B1 [2]
{for diagrams with no words maximum of 1 mark}

(d) wavelength = 4x0.12 = **0.48**m B1 [1]

(e) (labelled) diagram of <u>valid</u> arrangement: i.e for **longitudinal** waves B1
wave source stated: e.g. tuning fork/loud-speaker/oscillator/hand moving slinky- B1

explanation of how the standing wave is formed: e.g.
waves leaving wave sources **interfere/superpose** with reflected waves B1

18 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.

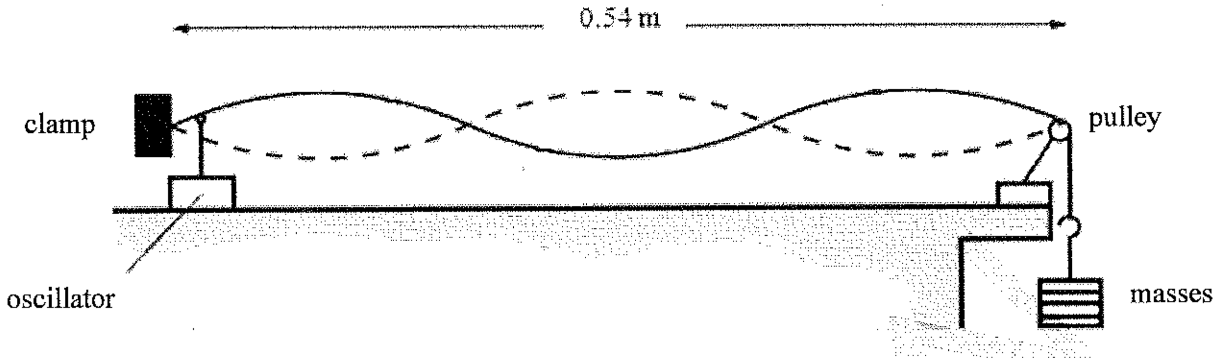

Fig. 18.1

(a) 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]**

Question			Answer	Marks	Guidance
18	(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} ≈ 22 (m s^{-1})	C1 C1 A1	
	(c)		$v \propto f$ and since $v \propto \sqrt{T}$, therefore $f \propto \sqrt{T}$ frequency will increase by a factor of $\sqrt{1.14} = 1.068$, therefore increase = 6.8 %	C1 A1	
			Total	7	

5 **(a)** When used to describe stationary (standing) waves explain the terms

(i) node ....

.... **[1]**

(ii) antinode. ....

.... **[1]**

(b) Fig. 5.1 shows a string fixed at one end under tension. The frequency of the mechanical oscillator close to the fixed end is varied until a stationary wave is formed on the string.

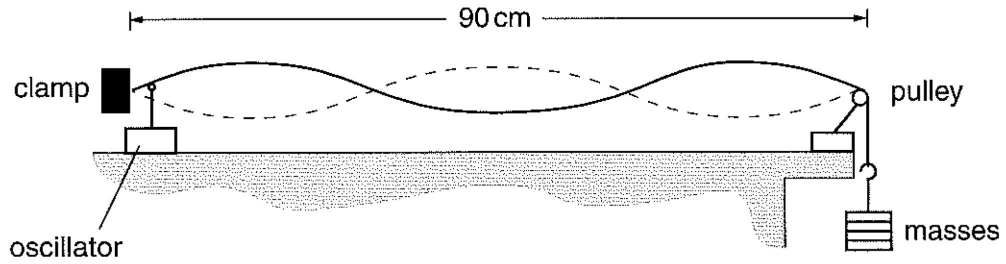

Fig. 5.1

(i) Explain with reference to a progressive wave on the string how the stationary wave is formed.

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.... **[3]**

(ii) On Fig. 5.1 label one node with the letter **N** and one antinode with the letter **A**. **[1]**

(iii) State the number of antinodes on the string in Fig. 5.1.

number of antinodes = ... **[1]**

(iv) The frequency of the oscillator causing the stationary wave shown in Fig. 5.1 is 120 Hz.

The length of the string between the fixed end and the pulley is 90 cm.

Calculate the speed of the progressive wave on the string.

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

(c) The speed v of a progressive wave on a stretched string is given by the formula

$$v = k\sqrt{W}$$

where k is a constant for that string. W is the tension in the string which is equal to the weight of the mass hanging from the end of the string.

In **(b)** the weight of the mass on the end of the string is 4.0 N. The oscillator continues to vibrate the string at 120 Hz. Explain whether or not you would expect to observe a stationary wave on the string when the weight of the suspended mass is changed to 9.0 N.

....

....

....

....

....

.... **[3]**

[Total: 13]

Question			Expected Answers	Marks	Additional Guidance
5	(a)	(i) (ii)	node occurs where the amplitude/displacement is (always) zero antinode occurs where the amplitude (of the standing wave) takes the maximum (possible) value	B1 B1	**accept** displacement for amplitude for **(i)** only
	(b)	(i)	wave travels to end and is reflected reflected wave interferes/superposes with incident wave always destructively at certain points to produce nodes **or** always constructively at certain points to produce antinodes	B1 B1 B1	**accept** 2 waves of same f travelling in opposite directions interfere with no reference to reflection
		(ii)	A and N points labelled correctly	B1	
		(iii)	3	B1	
		(iv)	30 cm = $\lambda/2$ or λ = 60 cm v = f λ = 120 x 0.6 v = 72 (m s^{-1})	C1 C1 A1	**allow** 1 mark for correct calculation using v = f λ with wrong wavelength if method/reasoning clear
	(c)		v = 2k becomes v = 3k (k = 36) wavelength increases by 3/2 (as frequency unchanged) 2 half wavelengths fit on the string so standing wave is set up/AW	B1 B1 B1	**accept** v increases by 3/2 or v = 108 m s^{-1} **accept** wavelength becomes 90 cm **allow ecf** correct conclusion with wrong λ
			Total question 5	**13**	

(e) An open tube is placed in front of the loudspeaker such that its far end is at point **Q**. See Fig. 4.2.

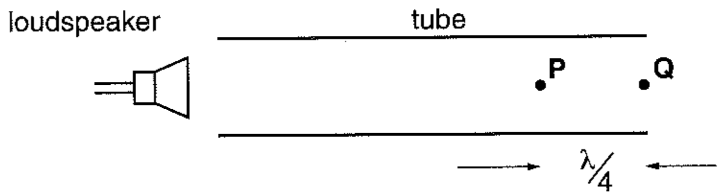

Fig. 4.2

(i) Explain how and under what conditions a stationary sound wave is formed in the tube.

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....

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.... **[3]**

(ii) Assume that the conditions are met for a stationary wave to be set up in the tube. The distance between the points **P** and **Q** is $\lambda/4$.

Describe the motion of the air molecules

1 at point **Q**

....

....

....

2 at point **P**.

....

....

.... **[3]**

[Total: 18]

Question			Answer	Marks	Guidance
4	(a)	(i)	f = 1000/2 f = 500 (Hz)	C1 A1	**give** 1 mark for ½ (POT error)
		(ii)	v = fλ giving 340 = 500 x λ λ = 0.68 (m)	C1 A1	**ecf(a)(i)**
	(b)		sinusoidal curve of same frequency and amplitude ± cosine curve	B1 B1	**must** be drawn for <u>2 full cycles</u> to score this mark **allow** drawn as sine curve from t = 0.5 ms
A A A	(c)		relates to the <u>oscillation</u> of two points on the (same) wave how far 'out of step' one oscillation is from the other/AW λ/4 means a phase difference of 90° or π/2 (rad)	B1 B1 B1	**accept** vibration **N.B.** statements about oscillations of two waves can only score the third marking point
	(d)		sine wave of same frequency with increased amplitude realisation that intensity is proportional to (amplitude)^2 giving amplitude increase by √2, i.e.2.8 mm	B1 B1 B1	
A A A	(e)	(i)	the wave <u>reflected</u> at the end of the pipe <u>interferes/superposes</u> with the incident wave to produce a resultant wave with nodes and antinodes both ends must be antinodes the pipe must be nλ/2 in length for this to happen	 B1 B1 B1 B1	**max** 3 marks
		(ii) 1	air molecules <u>oscillate</u> along the axis of the tube with maximum <u>amplitude</u>	B1 B1 B1	**max** 2 marks; **allow** vibrate; if transverse wave is clearly implied then can only score third marking point
		(ii) 2	no motion/nodal point	B1	**allow** zero displacement/amplitude
			Total	**18**	
			SCAN DOWN TO CHECK NO ANSWERS ON PAGE 11		

5 Fig. 5.1 shows a uniform string which is kept under 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.

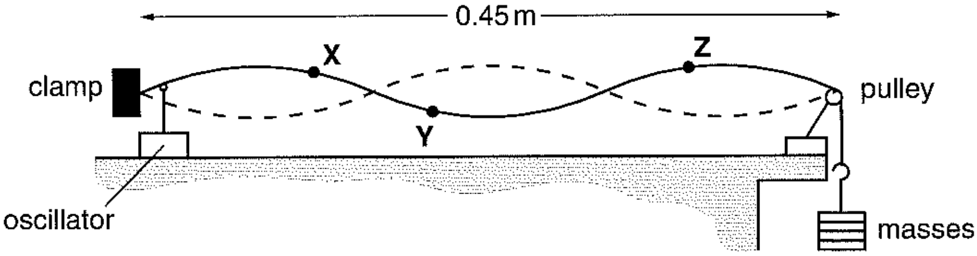

Fig. 5.1

(a) State two features of a stationary wave.

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.... **[2]**

(b) Explain how the stationary wave is formed on the string.

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.... **[2]**

(c) The distance between the clamp and the pulley is 0.45 m. **X**, **Y** and **Z** are three points on the string. **X** and **Y** are each 0.040 m from the nearest node and **Z** is 0.090 m from the pulley. State, giving a reason for your choice, which of the points **Y** or **Z** or both oscillate

(i) with the same amplitude as **X**

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....

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.... **[2]**

(ii) with the same frequency as **X**

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.... **[2]**

(iii) in phase with **X**.

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.... **[2]**

[Total: 10]

Question			Answer	Marks	Guidance
5	(a)		energy is trapped in pockets/ where the shape or energy does not move along/energy is stored/AW there are nodes/positions of zero amplitude/motion there are positions where there is max. amplitude/antinodes different/adjacent points have different amplitudes/AW all points between nodes in phase/all points in adjacent $\lambda/2$'s in anti-phase/AW	B1 B1 B1 B1 B1	**accept** any **two** sensible but different features **allow** there are nodes and antinodes as 1 marking point **penalise** displacement for amplitude once only
	(b)		incident wave is reflected (at the fixed end of the string) and the reflected wave (or it) interferes/superposes with the incident wave (to produce the stationary wave)	B1 B1	
	(c)	(i)	**points which are the same distance from the nodes will have the same amplitude** so **Y** (has the same amplitude as **X**)	**M1** A1	**N.B.** some will add **Z** stating it is the same distance from the node – these candidates can score the first mark
		(ii)	**all points on the string oscillate with the same frequency** so **Y** and **Z** (have the same f as **X**)	**M1** A1	
		(iii)	**all points in alternate segments of the string oscillate in phase/AW** so **Z** (is in phase with **X**)	**M1** A1	**accept** e.g. have positive displacement at the same time
			Total	**10**	

6 **(a)** Describe, in terms of vibrations, the difference between a longitudinal and a transverse wave. Give one example of each wave.

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.... **[4]**

(b) Fig. 6.1 shows a loudspeaker fixed near the end of a tube of length 0.6 m.

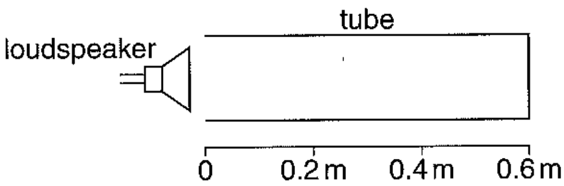

Fig. 6.1

The far end of the tube is closed. The frequency of the sound emitted from the loudspeaker is increased from zero. At a particular frequency a stationary wave is set up in the tube and the sound heard is much louder.

Explain how a stationary wave is formed in the tube.

In your answer, you should make clear how the stationary wave arises.

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.... **[3]**

(c) Figs. 6.2 and 6.3 show stationary wave patterns of amplitude against position along the tube at the fundamental frequency f_0 and the next possible harmonic at frequency $3f_0$.

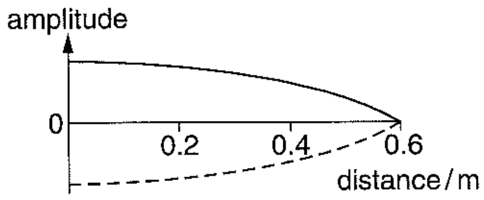

Fig. 6.2

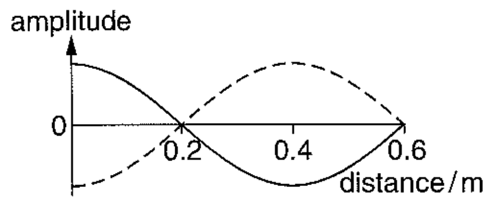

Fig. 6.3

Describe the motion of the air in the tube containing the stationary wave

(i) at points 0 m, 0.2 m and 0.6 m in Fig. 6.2

....

....

.... **[2]**

(ii) at points 0 m, 0.2 m and 0.4 m in Fig. 6.3.

....

....

.... **[2]**

(d) The end of the tube at 0.6 m from the loudspeaker is now opened.

(i) On Fig. 6.4 sketch the stationary wave pattern of amplitude against position along the tube at the new fundamental frequency. **[2]**

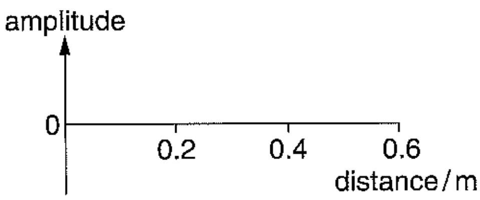

Fig. 6.4

(ii) State how the frequency of this stationary wave is related to the frequency f_0 of Fig. 6.2.

.... **[1]**

[Total: 14]

Question			Expected Answers	M	Additional Guidance
6					
	a		oscillation/vibration of <u>particles/medium</u> in direction of travel of the wave example: sound wave, etc. oscillation/vibration of <u>particles/medium</u> (in the plane) at right angles to direction of travel of the wave example: surface water waves, string, electromagnetic, etc	B1 B1 B1 B1	**allow** direction of energy transfer of the wave **not** direction of wave motion **allow** direction of energy transfer of the wave **allow** RE mark for weaker descriptions with same omissions as in longitudinal wave
	b		the incident wave is reflected at the end of the pipe <u>reflected</u> wave <u>interferes/superposes</u> with the incident wave to produce (a resultant wave with) nodes and/or antinodes	B1 B1 B1	 **QWC mark** **accept** resultant wave with no energy transfer
	c	i	at 0 oscillation with max amplitude along tube at 0.2 m (oscillation along tube with) smaller amplitude at 0.6 m no motion/node	B1 B1	**not** displacement (penalise only once) all 4 correct for 2 marks; 2 correct for 1 mark
		ii	oscillation at 3 times the frequency of c(i) at 0 (oscillation with) max amplitude (along tube)/antinode at 0.2 m no motion/node at 0.4 m motion as at 0 (but in antiphase/opposite direction)	B1 B1	 3 correct for 2 marks; 2 correct for 1 mark
	d	i	$\lambda/2$ sketch with zero at 0.3 m	M1 A1	**accept** 1 or 2 lines, solid or dotted
		ii	$2f_0$	B1	**no ecf from d(i)**
			Total question 6	**14**	

6 In an investigation of standing waves, sound waves are sent down a long pipe, with its lower end immersed in water. The waves are reflected by the water surface. The pipe is lowered until a standing wave is set up in the air in the pipe. A loud note is then heard. See **Fig. 6.1**.

Length l_1 is measured. The pipe is then lowered further until a loud sound is again obtained from the air in the pipe. Length l_2 is measured.

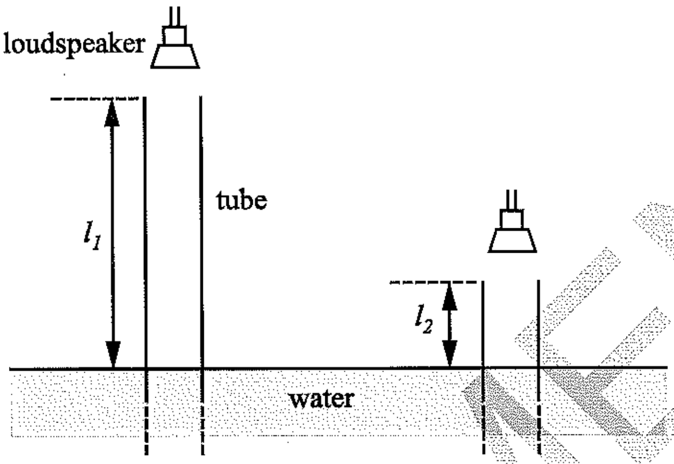

Fig 6.1

(a) A student obtained the following results in the experiment.

frequency of sound/Hz	l_1 **/m**	l_2 **/m**
500	0.506	0.170

Use data from the table to calculate the speed of sound in the pipe.
Show your reasoning.

speed = ... m s^{-1} **[4]**

(b) The student repeats the experiment, but sets the frequency of the sound from the speaker at 5000 Hz.

Suggest and explain whether these results are likely to give a more or less accurate value for the speed of sound than those obtained in the first experiment.

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.... **[2]**

(c) The pipe is removed from the water and laid horizontally on a bench as in **Fig. 6.2**. The frequency of the sound waves sent down the pipe is adjusted until a standing wave is set up in it. Point **P** is a distance of $\lambda/4$ from point **Q** at the far end.

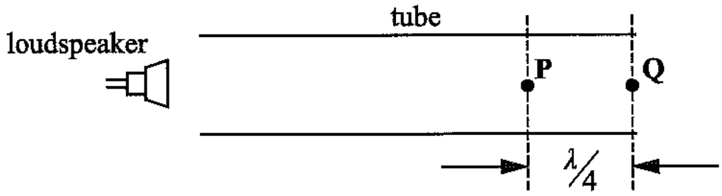

Fig. 6.2

Explain how and under what conditions a stationary sound wave is formed in the pipe. Describe and compare the motion of the air molecules at points **P** and **Q**.

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.... **[6]**

Question			Answer	Marks	Guidance
6	(a)		tube pushed into water by $\lambda/2$ therefore $\lambda/2 = 0.506 - 0.170$ giving $\lambda = 0.672$ (m) using $v = f\lambda$ $v = 500 \times 0.672 = 336$ (m s^{-1})	B1 B1 C1 A1	allow any statement about antinode needed at open end and node at water level. A solution worked to 2 SF will score a maximum of 3 marks.
	(b)		smaller λ means smaller *l* to measure, so less accurate measurement. added detail or expansion of argument.	B1 B1	
	(c)		the wave reflected at the end of the pipe interferes/superposes with the incident wave . to produce a resultant wave with nodes and antinodes. both ends must be antinodes **or** the pipe must be $n\lambda/2$ in length for this to happen. at **Q** air molecules <u>oscillate</u> with motion along the axis of the tube **or** with maximum amplitude. at **P** no motion/nodal point.	B1 B1 B1 B1 B1 B1	 **allow** vibrate.
			Total	**12**	

7 An estimation of the speed of electromagnetic waves can be made using the hot spots inside a microwave oven. Microwaves are emitted in all directions inside the metal walls of the oven at a frequency of 2.5×10^9 Hz causing stationary waves to be set up. Fig. 7.1 shows a typical pattern of the centres of the hot spots marked **X** in the central area of the floor of the oven.

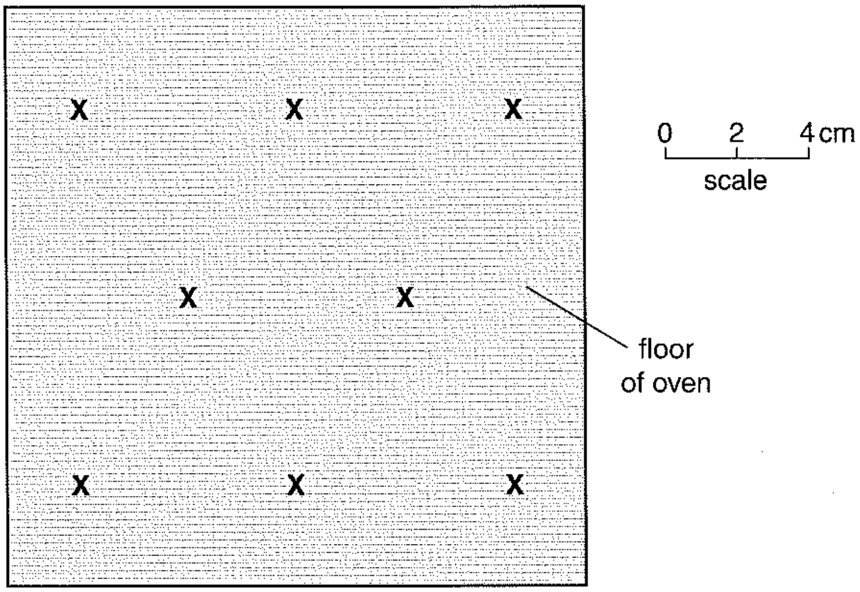

Fig. 7.1

These positions can be located to within a few millimetres by melting small areas in a bar of chocolate placed on the floor of the oven for a few seconds.

(a) Explain how a stationary microwave pattern is set up in the oven.

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.... **[3]**

(b) Explain whether the points marked **X** on Fig. 7.1 are at nodes or antinodes in the wave pattern.

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.... [2]

(c) Fig. 7.1 is drawn to **half scale.** By using measurements taken from the diagram make an estimate of the speed *c* of the microwaves. Make your reasoning clear.

c = ... $m\,s^{-1}$ **[4]**

[Total: 9]

Question			Answer	Marks	Guidance
7	a		(micro)waves are <u>reflected</u> (at the metal walls) reflected waves interfere/superpose with the incident waves to produce nodes and antinodes (– a stationary wave pattern)	B1 B1 B1	**allow** points of constructive and destructive interference
	b		X are the points of <u>maximum</u> energy/intensity/amplitude so are antinodes	M1 A1	**allow** displacement in this case
	c		measurement = 3 cm **or** $\lambda/2$ = 6 cm so $\lambda = 0.12$ m $c = f\lambda = 2.5 \times 10^9 \times 0.12$ $= 3.0 \times 10^8$ (m s^{-1})	B1 C1 M1 A1	measurement to within ± 1 mm **ecf** measurement, i.e. λ = 4 x measurement there must be a valid calculation shown scores 1 out of final 3 for answer of 1.5×10^8 **allow** 1 SF, i.e. 3×10^8
			Total	9	

4 (a) Fig. 4.1 shows a section of a uniform string under tension at one instant of time. A progressive wave of wavelength 80 cm is moving along the string from left to right. At the instant shown, the displacement of the string is zero at the point opposite the zero mark on the scale beneath the string.

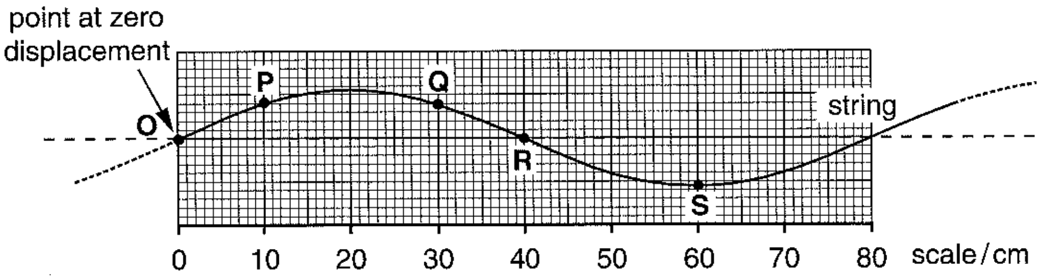

Fig. 4.1

Four points **P**, **Q**, **R** and **S** at 10, 30, 40 and 60 cm respectively, are marked on the string. The oscillatory motion of each point can be described in terms of amplitude, frequency and phase difference from **O**.

(i) State the meaning of each of the terms

1 *amplitude*

....

....

2 *frequency*

....

....

3 *phase difference.*

....

.... **[3]**

(ii) Describe using these three terms how the motion of points **P**, **Q**, **R** and **S**

1 is similar,

....

....

2 is different.

....

.... **[2]**

(b) Fig. 4.2 shows the same section of string now held under tension between a clamp and a pulley, 80 cm apart. A mechanical oscillator is attached to the string close to the clamped end. The frequency of the mechanical oscillator is varied until the stationary wave shown is set up between the clamp and the pulley. The same four points as in Fig. 4.1 are marked on the string.

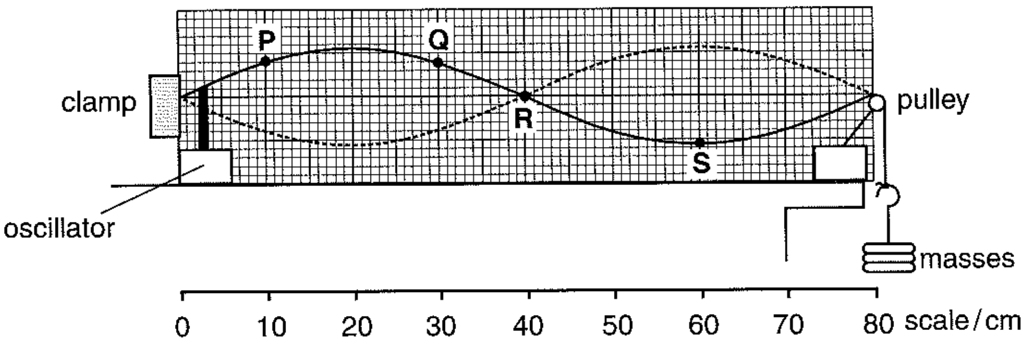

Fig. 4.2

(i) Describe how a stationary wave is different from a progressive wave.

....

....

....

....

.... **[2]**

(ii) Explain how the stationary wave is formed on this string.

....

....

....

....

....

.... **[3]**

(iii) Describe, using the terms amplitude, frequency and phase difference, how the motions of the points **P**, **Q** and **S**

1 are similar,

....

....

2 are different.

....

.... **[3]**

(iv) In Fig. 4.2 the frequency of oscillation is 30 Hz. State, with a reason, the lowest frequency of oscillation of the string at which the motions of all of the points **P**, **Q**, **R** and **S** are

1 in phase,

....

....

2 all at rest.

....

.... **[4]**

Question			Answer	M	Guidance
4					
	a	i 1	the maximum displacement <u>from equilibrium</u> or <u>rest position</u>	B1	**allow** *zero* or *undisturbed* for *equilibrium*
		2	number of oscillations/vibrations (at a point) <u>per</u> unit time	B1	number of <u>wavelengths</u> passing a point or produced by the wave source <u>per</u> unit time **allow** <u>per</u> second **NOT** *amount* for *number*
		3	how far 'out of step' (out of sync) the oscillations <u>at two points</u> on the wave/string are/AW	B1	**alt e.g.** the fraction of a cycle between the oscillations at the two points
		ii 1	all have same frequency **or** same amplitude	B1	**N.B.** withhold mark if extra incorrect answers given
		2	all have different phases/ phase differences	B1	**allow** *not in phase* or *all out of phase*
	b	i	*progressive* a wave which transfers energy *stationary* a wave which <u>traps/stores</u> energy (in pockets) **or** *progressive* : transfers shape/information from one place to another *stationary* where the shape does not move along/which has nodes and antinodes/AW	B1 B1	**accept** phase relationship descriptions between different points on wave; must be a comparison for same property to score both marks
		ii	the wave <u>reflected</u> (at the fixed end of the wire) <u>interferes/superposes</u> with the incident wave to produce a resultant wave with nodes and antinodes/no energy transfer	B1 B1 B1	
		iii 1	(**all** points have) same frequency **P** and **Q** have same amplitude <u>and</u> (are in) phase	B1 B1	**allow** *same phase difference* here
		2	**S** has larger amplitude than **P** <u>and</u> **Q** **S** has a phase difference of π/in antiphase to **P** <u>and</u> **Q**	B1 B1	**allow** *different to* **or** 180° **max** any 3 out of 4 marking points
		iv 1	15 Hz as all points in the fundamental/first harmonic mode move in phase	B1 B1	**accept** string is ½ λ long/between ends
		2	120 Hz for every 10 cm to be at rest λ = 20 cm (so 4 x frequency of Fig. 4.2)	B1 B1	**accept** as all points are nodes **or** $f = 8f_0$ **or** is 8[th] harmonic
			Total question 4	**17**	