Mark schemes

1 A

[1]

2 D

[1]

3 A

[1]

4 C

[1]

5 A

[1]

6 C

[1]

7 C

[1]

8 B

[1]

9 C

[1]

10 C

[1]

11 D

[1]

12 A

[1]

13 **Two** of

B1

Mass or mass/unit length

B1

Tension
Length
Temperature

[2]

14 (a) 4 mm

B1

1

(b) 3:1; 3/1

C1

9 **or** 9:1

A1

2

[3]

15

amplitude: each point along wave **(1)**
has <u>same</u> amplitude for progressive wave
but varies for stationary wave **(1)**

phase: progressive wave, adjacent points vibrate with different phase **(1)**
stationary wave, between nodes all particles vibrate in phase
[or there are only two phases] **(1)**

energy transfer: progressive wave, energy is transferred through space **(1)**
stationary wave, energy is not transferred through space **(1)**

[5]

16 (a) (i) one loop shown

B1

(1)

(ii) 0.68 m

B1

(1)

(iii) two equal length loops shown

B1

(1)

(b) frequency increases

B1

(1)

[4]

17 (a) *superposition* (of progressive waves) B1

incident wave and reflected wave/wave reflected through 180^{O}/waves travelling in opposite directions B1

same frequency/wavelength B1

in same medium. B1

Any 3 out of 4 points **3**

(b) $f = c/\lambda$ C1

$\lambda = 1.24$ C1

f = 258 Hz A1

e.g. f = 512 gets 1 mark **3**

[6]

18 **The student's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The student's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

Answers may cover some of the following points:

- *(1) a wave and its reflection / waves travelling in opposite directions meet / interact / overlap / cross / pass through etc*

    point (1) must be stated together i.e it should not be necessary to search the whole script to find the two parts namely the directions of the waves and their meeting
- *(2) same wavelength (or frequency)*
- *(3) node − point of minimum or no disturbance*

    points (3) may come from a diagram but only if the node is written in full and the y-axis is labelled amplitude or displacement
- *(4) antinode − is a point of maximum amplitude*

    point (4) may come from a diagram but only if the antinode is written in full and the y-axis is labelled amplitude or displacement
- *(5) node - two waves (always) cancel / destructive interference / 180° phase difference / in antiphase [out of phase is not enough] (of the two waves at the node) [not peak meets trough]*
- *(6) antinode − reinforcement / constructive interference occurs / (displacements) in phase*
- *(7) mention of <u>superposition</u> [not superimpose] of the two waves*
- *(8) energy is not transferred (along in a standing wave).*

    if any point made appears to be contradicted elsewhere the point is lost − no bod's

High Level (Good to excellent): 5 or 6 marks
The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

*6 marks: points (1) **AND** (2) **with** 4 other points which must include point (4) or the passage must indicate that the wave is oscillating at an antinode*

*5 marks: points (1) **AND** (2) **with** any three other points*

although point (1) may not be given as a mark the script can be searched to see if its meaning has been conveyed as a whole before restricting the mark and not allowing 5 or 6 marks

Intermediate Level (Modest to adequate): 3 or 4 marks
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

*4 marks: (1) **OR** (2) **AND** any three other points*
3 marks: any three points

Low Level (Poor to limited): 1 or 2 marks
The information conveyed by the answer is poorly organised and may not be relevant or

coherent. There is little correct use of specialist vocabulary.
The form and style of writing may be only partly appropriate.

2 marks: any two points
1 marks: any point or a reference is made to both nodes and antinodes

[6]

19 (a) π / 180° out of phase ✓

*Do **not** allow "out of phase".*

1

(b) wavelength = 0.44 m ✓

c (= $f\lambda$) = 145 (m s^{-1}) ✓

2

(c) First harmonic frequency = 110 Hz✓

$T = 4 \times 110^2 \times 0.66^2 \times \left(\frac{3.1 \times 10^{-8}}{0.91}\right)$✓

71.8 N✓

3

(d) Extension of string = $3 \times 2\pi \times 3.0 \times 10^{-3}$ (= 5.65 cm)✓

energy stored = 0.5 × 71.8 × 0.0565 = 2.03 (J)✓

Compares calculated energy quantitatively to another energy and draws correct inference, e.g. wire would be moving at about 80 mph so a risk / 2 J is the equivalent of 1 kg mass dropped through 0.2 m so a risk✓

3

[9]

20 (a) waves are <u>reflected</u> (from the oven wall) ✓

1

and superpose/interfere with wave travelling in opposite direction/incident waves/transmitted wave ✓

NOT superimpose

1

(b) energy/amplitude is maximum ✓

1

(chocolate melts at) antinode ✓

if refer to node can still be awarded first mark

1

(c) clear evidence that used first and third antinode ✓

can be from diagram

1

distance from first to third antinodes = 0.118 ± 0.001 (m) OR
distance between two adjacent antinodes = 0.059 ± 0.001(m) ✓

mark for either value

carry their value forward for subsequent marks even if outside tolerance

1

wavelength = 0.118 (m) ✓

mark for using their wavelength (range 0.112 to 0.124)

1

frequency = 3.0×10^8 /0.118 ✓

mark for use of $v = f\lambda$ allow this mark if use 0.059

1

frequency = 2.5×10^9 (Hz) ✓

must *be in range $2.40 \times 10^9 - 2.60 \times 10^9$*

if use 330 for speed lose last 2 marks

1

(d) position of antinode/maximum energy/maximum amplitude/nodes (in food) continually changes ✓

must be clear antinode maximum energy/maximum amplitude changes location

1

[10]

21 (a) (i) oscillates / vibrates ✓

(allow goes up and down / side to side / etc, <u>repeatedly, continuously, etc</u>)

about <u>equilibrium</u> position / perpendicularly to central line ✓

2

(ii) X and Y: antiphase / 180 (degrees out of phase) / π (radians out of phase) ✓

X and Z: in phase / zero (degrees) / 2π (radians) ✓

2

(b) (i) $v = f\lambda$

= 780 x 0.32 / 2 or **780 x 0.16 OR 780 x 320 / 2** or **780 x 160** ✓

THIS IS AN INDEPENDENT MARK

= 124.8 ✓ (m s^{-1}) correct 4 sig fig answer must be seen

2

(ii) ¼ cycle ✓

$T = 1 / 780$ OR $= 1.28 \times 10^{-3}$ ✓

$0.25 \times 1.28 \times 10^{-3}$

$= 3.2 \times 10^{-4}$ (s) ✓

Allow correct alternative approach using distance of 0.04m ✓

travelled by progressive wave in ¼ cycle divided by speed.

0.04 /125 ✓ $= 3.2 \times 10^{-4}$ (s) ✓

3

(c) (i) antinode ✓

1

(ii) 2 x 0.240 ✓

= 0.48 m ✓ '480m' gets 1 mark out of 2

2

(iii) ($f = v/\lambda$ = 124.8 or 125 / 0.48) = **260** (Hz) ecf from cii ✓

1

[13]

22 (a) tension – newtonmeter

B2

or tension – from mass on balance

B1

and – multiply by g

B1

mass – balance / scales

B1

length – rule / tape / ruler

B1

(4)

(b) frequency read from signal generator when standing wave produced / use of strobe etc.

B1

measure λ using several loops or full length of string

B1

node → node / each loop = λ / 2

B1

use of $c = f\lambda$

B1

(4)

(c) $\lambda = 0.40$ (m) **C1**

$c = 60.8$ (m s^{-1}) e.c.f. from λ **C1**

$T = 7.06$ (N) **C1**

$\mu = 1.9(1) \times 10^{-3}$ (kg m^{-1}) c.a.o. **A1**

$m = 2 \times \mu$ value (= 3.8×10^{-3} kg or equivalent unit) e.c.f. s.f.p. applied only at this answer **B1**

(5)

[13]

23 (a) Initially the path difference is zero/the two waves are in phase when they meet/the (resultant) displacement is a maximum ✓

Alternative:

Constructive interference occurs when the path difference is a whole number of wavelengths and the waves are in phase

1

As the movable tube is pulled out, the path difference increases and the two waves are no longer in phase, so the displacement and loudness decrease ✓

Destructive interference occurs when the path difference is an odd number of half wavelengths and the waves are in antiphase

1

When the path difference is one half wavelength, the two are in antiphase and sound is at its quietest. ✓

Initially the path difference is zero and the sound is loud

1

As the path difference continues to increase, the two waves become more in phase and the sound gets louder again. ✓

As the pipe is pulled out the path difference gradually increases, changing the phase relationship and hence the loudness of the sound

1

(b) Use of *wavelength = speed / frequency*

The first mark is for calculating the wavelength

1

To give: 340 / 800 = 0.425 m ✓

Path difference = one half wavelength = 0.21 m ✓

The second mark is for relating the wavelength to the path difference

Path difference = 2 ($d_2 - d_1$) = 2 (distance moved by movable tube)

1

Distance moved by movable tube = 0.10 m. ✓

The final mark is for relating this to the distance moved by the tube and working out the final answer.

1

(c) Start with d1 = d2

(Alternative mark scheme involving changing frequency and measuring to first min for each one can gain equal credit)

Measure distance moved by movable tube for each successive minima and maxima✓

Start with d1 = d2

Measure distance moved by movable tube for first minimum.

1

Each change in distance is equal to one quarter wavelength. ✓

Distance is equal to one quarter wavelength

1

Continue until tube is at greatest distance or repeat readings for decreasing distance back to starting point. ✓

Repeat for different measured frequencies.

1

Use speed = frequency x wavelength ✓

Use speed = frequency x wavelength)

1

[11]

24 (a) (i) d / 7.5 and d / 5.0 (denominator may be in m s^{-1})

or d / 7.5 and d / 7.5 + 1.5

or d / 5.0 – .5 and d / 5.0

B1

(1)

(ii) d / 7.5 + 1.5 = d / 5.0

C1

22.5 (22 – 23) km

A1

(2)

(b) (i) interference / superposition of waves (condone waves superimpose) of: same frequency travelling in opposite directions

or an incident and a reflected wave

B1

idea of a resonant length
eg length of string is a whole number of half wavelengths of the wave

or length such as to produce nodes and antinodes

or fixed ends are nodes

B1

(2)

(ii) wavelength of fundamental = 64 m

C1

v = fλ

C1

2.8 Hz

A1

(3)

(iii) (natural / fundamental) frequency of oscillation of the new spans

= 2 × (ii) (5.6 Hz) or twice original frequency

or wavelength is half the original wavelength(= 32 m)

M1

clear link and conclusion shown between the new natural frequency of the spans
and the max frequency of the earthquake

examples:

second calculation plus conclusion that resonant vibrations would not take place

or calculation and comparison of the wavelength of the earthquake wave travelling along the bridge and the resonant wavelength (42 m and 32 m)

A1

(2)

[10]

25 (a) (i) Number of complete waves passing a point **in one second** / number of complete waves produced by a source **in one second** / number of complete vibrations (oscillations) **per second** / number of compressions passing a fixed point **per second**

1

(ii) 180° phase difference corresponds to ½ λ

Use of $v = f\lambda$ with correct powers of 10

0.33 (m)

3

(b) (i) Do not have the same frequency

do not have a constant phase difference

2

(ii) Waves meet antiphase

Undergo superposition

Resulting in destructive interference

3

(iii) T = 100 ms

Use of $T = 1 / f$ or beat frequency (Δf) = 10 Hz

500 (Hz) (allow 510 –their beat frequency)

3

(c) (i) Only box ticked: Quality

1

(ii) Add regular alternating voltages together

With appropriate amplitudes

Where frequencies of voltages match the harmonics of sound / where frequencies are multiples of 440 Hz

Allow 2 for sampling sound (at twice max frequency) B1

Convert to binary (and replay through D to A converter). B1

3

[16]

Examiner reports

5

This proved to be one of the more demanding questions on the paper, with 39% of students being correct, despite the equation being in the data booklet. The most popular distractor was C, chosen by students having difficulty dividing √2 by 2 perhaps. Unsurprisingly B was also popular, the answer obtained if the two changes cancelled out.

13

There were many correct answers to this question. Incorrect responses were usually couched in terms of the amplitude of the wire and the frequency of the signal.

14

Many candidates were able to complete the task of adding together two amplitudes from the graph. For the minority, 2 mm rather than 4 mm was a very common error. Graph labels provided a substantial number of unit errors in this question.

Few of the candidates were comfortable with the calculation of intensity ratio from the graph. Examiners saw many examples of 3:1 (the amplitude ratio), usually with no explanation for the origin of the ratio. In other cases the ratio was calculated the wrong way around (1:3 or 1:9) or candidates worked on the basis of an inverse-square law calculation.

15

It was evident that the depth of knowledge necessary to answer this question was not available to the majority of candidates. Even the energy transfer section in part (c) was the source of wrong or vague or inadequate answers.

17

Part (a) was generally not answered well; in part because the conditions were not known, but also as result of poor writing skills.

Failure to realise that the wavelength was twice the length of the guitar string was a very common error in part (b). Of the candidates who did get the calculation right, many lost a mark for quoting too many significant figures in the final answer.

18

Almost all students made a good effort at answering this question and almost all of those knew that standing waves are constructed from two waves. This being the case it was appropriate that this question was the basis of the quality of written communication assessment in this examination. Weaker students often spent too long setting the scene. They gave details of the apparatus and explained how the string was plucked or vibrated before the bullet points were addressed. Often at this stage these were answered with very brief responses that gave very little detail. The middle ability group of students fared much better. They could describe what nodes and antinodes were and how they came about in terms of the interference of two waves. What was often missing was the fact that the two waves that superpose have the same frequency or wavelength. Many of this group and a large percentage of the top ability group understood that an antinode was a maximum of the motion but they referred to the maximum displacement rather than the maximum amplitude. A couple of points separated this top group from the middle students as well as the quality of the structure of their writing and spelling. First they referred to the waves superposing unlike the majority who thought the waves superimposed on each other. Secondly, they sometimes included a point about the lack of energy transmission in a standing wave.

20 This question about the formation of stationary waves in a microwave oven was answered well by a good proportion of students. In part (a) the idea of reflection taking place was clearly stated in the majority of answers. The second marking point explaining how this resulted in the reflected and incident wave superposing was more discriminating. A significant proportion of students stated that the waves superimposed rather than superposed. Part (b) was only fully answered by those students who, having identified the melted chocolate positions as antinodes were then able to explain that this is where the amplitude of the wave was a maximum. Weaker responses tended to identify these positions as nodes or did not link the melted chocolate to stationary waves at all. Part (c) was a five mark calculation and this produced very good discrimination. About a third of students were awarded 4 or 5 marks. To obtain full marks students were required to give a clear indication, either on the diagram or in their working, that they had measured the distance between the first and third dot rather than measuring from the first to second dot and then doubling. It was sometimes hard to establish exactly what students had measured and it should be appreciated that showing full working in these extended calculations is very important. A lot of vague answers were seen to question 2.4 and it was the physics that needed to be explained. A common response was 'to cook the food evenly' and this was not seen as a physics explanation.

21 Part (a)(i) was almost universally misinterpreted due to a similar question appearing on a previous paper. Many students interpreted the question as 'describe the motion over the next cycle'. Those who did this often failed to point out that there was a continuing oscillation taking place. Part (a)(ii) was very poorly answered which was a surprise. A common answer was 'out of phase' for X and Y which is not equivalent to 'antiphase'. Phase was often given in terms of number of wavelengths, e.g. ½λ. There was little understanding of the difference between phase difference along a progressive wave and a stationary wave. Many had measured the fraction of a wavelength between the points and converted this into an angle as you would for a progressive wave. It is suggested that phase difference along a stationary wave be demonstrated by referring to the many simulations available.

Part (b)(i) presented few problems for students. In part (b)(ii) many students did 1/780 and obtained the time for one complete cycle but did not recognise that they needed to divide by 4 to get the time for ¼ of a cycle. A significant number thought that the time between maximum displacement and reaching the equilibrium position was half a cycle. Some divided 780 by 4 which makes the answer 8 times greater than it should be.

For part (c)(i) most students got 'antinode' but a significant number put 'node'/ 'amplitude'/ 'max displacement' / 'stationary wave' / 'equilibrium' / 'maxima'. Part (c)(ii) presented few problems for students. In part (c)(iii) quite a few students left this blank because they were unable to answer the previous question. However, many of those who scored the mark did so by using an incorrect answer to (c)(ii). Students should be encouraged not to give up; the final part of a question is not necessarily the hardest.

22

(a) The majority of candidates were able to suggest what quantities needed to be measured in order to calculate the speed of the waves however many of these failed to give suitable measuring instruments with which to make the measurements.
Surprising few candidates suggested using a newton meter in order to measure the tension in the string.

(b) This was often too loosely answered with insufficient detail of how multiple loops should be used in order to measure an accurate value for the wavelength. Again many candidates failed to explain that the calibrated signal generator would give a value for the frequency of the wave.

(c) This was often the part most successfully answered by candidates. Although many gave a value for the wavelength of 0.20 m, with error carried forward this still gave access to the remaining four marks. Only the strongest candidates tended to multiply the value for μ by the 2 m that gave the total mass of the string.

25

(a) (i) Acceptable definitions were given by a good majority of the students. Those who failed to produce a satisfactory response usually omitted reference to time.

(ii) Most gained credit for the use of $v = f\lambda$. The common errors were ignoring the k in kHz and not calculating $\lambda/2$.

(b) (i) This question was a 'twist' on a commonly asked question that requires students to explain what is meant by waves being coherent. This question required students to identify that the tuning forks had different frequencies and would not have a constant phase difference when they arrive at a point so would not be coherent. This proved to be too challenging for many students.

(ii) This was poorly done and fewer than half the students were able to give at least one acceptable point worthy of credit and there were relatively few who gained full credit. One can only speculate that students have difficulty understanding interference that occurs due to changes in phase difference that take place at a point with time as is the case in this instance.

(iii) A high proportion of the students gained credit for use of $f = 1/T$ and many of these arrived at the correct beat frequency. Many did no more than this and relatively few of these went on to calculate the correct frequency of the fork that emitted the lower frequency.

(c) (i) Almost three quarters of the students selected the correct response to this question.

(ii) Relatively few appreciated the meaning of synthesis of sound ie the process of adding together sinusoidal waves of appropriate frequencies and amplitude to produce a required sound. Students were given compensatory credit for explaining the process of sampling a sound and storing it digitally.