A-Level Physics

Superposition and Stationary Waves

Mark Scheme

Time available: 89 minutes
Marks available: 65 marks

1. (a) **Max 2**

Antiphase / completely out of phase / π radian out of phase ✓

Allow ½ cycle or 180° out of phase

Condone:

'Move in opposite directions'

'Displaced in opposite directions'

'when P is at its peak then Q is at its trough'

for loose descriptions of antiphase

'Opposite amplitudes' too vague (treat as neutral)

'When P is positive Q is negative' too vague

Similar amplitudes (of vibration) **or** similar (magnitudes of) displacement (at any instant in time) ✓

Same period **or** same frequency ✓

Move with the same speed ✓

Allow same amplitude / same (magnitude of) displacement

2

(b) Use of $v = f\lambda$ or determines the wavelength = 0.275 m ✓

Condone use of wavelength = 0.55 m or

0.1375 m in substitution for 1st MP

Condone Power of ten errors on wavelength for 1st MP

Two errors forfeit 1st mark:

Allow wavelength in range 0.27 to 0.28 m

(v =) 69 m s^{-1} ✓

Allow answers in range 67.5 to 70.0 m s^{-1}

2

(c) Same speed ✓

Moving in opposite directions ✓

same wavelength / same frequency/ similar amplitudes ✓

The following are insufficient:

Progressive / transverse / transfer energy

Allow same amplitudes

3

(d) Horizontal line drawn from **P** to **Q** ✓

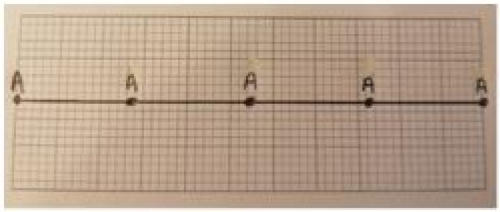
1

(e) Marks an A at each end of the string ✓

Condone other incorrect antinodes or nodes drawn (1st MP)

Marks all 5 As (evenly spaced by eye) on a horizontal line ✓
cao

Penalise incorrect number A or poorly positioned A (2nd MP)



2

(f) Third harmonic / third harmonic drawn in **Figure 6** ✓

Frequency for first harmonic has reduced to 1/3 of previous or

$f = \frac{1}{3} \times \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

or

speed reduces to 1/3 of previous ✓

String being driven at three times this frequency ✓

*Must be a clear statement that this is 3rd harmonic / accept 3 symmetrical loops drawn in **Figure 6***

*Where no other mark has been scored allow **1 mark** for:*

- *Speed decreases*
- *Fundamental frequency is lower/ frequency of 1st harmonic is lower*
- *use of*

$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

where 9μ has been substituted correctly (accept in any correct rearrangement)

3

[13]

2. (a) Substitution of data in $Y = \frac{FL}{A\varepsilon}$

3.1×10^{-3} (m) ✓

2 marks can be awarded if 4mm used to show T>500 N provided an explanation is provided, otherwise award zero.

2

(b) (500 = Tcos 65)

T = 1200 N ✓

1

(c) Wind produces a wave / disturbance that travels along the wire ✓

Wave is reflected at each end / waves travel in opposite directions✓

(Incident and reflected) waves interfere / superpose ✓

Only certain frequencies since fixed ends have to be nodes. ✓

4

(d) Mass per m of the wire = 0.14(2) kg ✓

1

(e) Use of $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}(= 2.47)$ to find fundamental

(or $f = \frac{3}{2l}\sqrt{\frac{T}{\mu}}$)

Third harmonic = 7.4 (Hz) ✓

The second mark is for multiplying the fundamental frequency by 3 – allow ecf

2

(f) Diagram showing three approximately equally spaced loops

Condone single line

1

(g) Copper may be stretched beyond elastic limit / may deform plastically ✓

Permenant deformation / Does not return to original length ✓

Allow 'will remain longer than original' or 'will be permenantly deformed'

2

[13]

3. (a) 180 degrees

accept ° for degrees

OR

π radians ✓

condone ^{c} or 'rad' for radian

reject 'half a cycle'

treat 'π radians in phase' as talk out

1

(b) (idea that) sets of combining waves do not have the same amplitude ✓

condone 'waves do not have same intensity' or 'same energy' or 'some energy is absorbed on reflection' or 'same power' or 'same strength' or idea that non point source or non point receiver would lead to imperfect cancellation

condone the idea that the waves may not be monochromatic

ignore 'some waves travel further' or 'waves do not perfectly cancel out'

reject 'waves may not be 180° out of phase'

1

(c) valid use of a set square or protractor against TR (to ensure perpendicular) $_1$ ✓

measure x at two <u>different</u> points [at each end of M] <u>**and**</u> adjust until [make sure] both <u>distances are the same</u> $_2$ ✓

OR

use of set square to align M with the perpendicular line earns $_2$ ✓

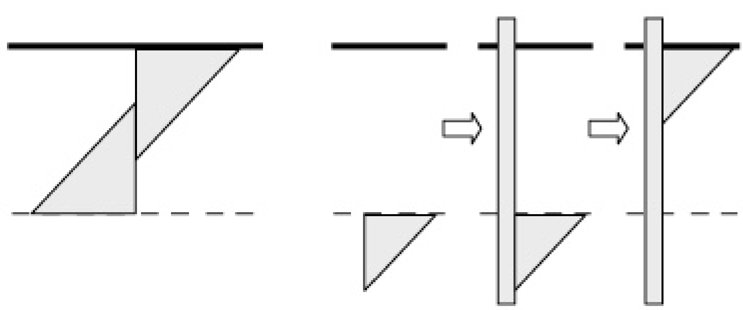
if method used does not allow <u>continuous</u> variation in x then award maximum 1 mark

OR

align <u>graph paper</u> with TR $_1$ ✓

align M with grid lines on graph paper $_2$ ✓

both marks can be earned for suitable sketch showing a viable procedure involving one or more recognisable set squares or protractors; the sketch may also show a recognisable ruler, eg



allow use of scale on set square to measure the perpendicular distances don't penalise incorrect reference to the set square, eg as 'triangular ruler', as long as the sketch shows a recognisable set square

2

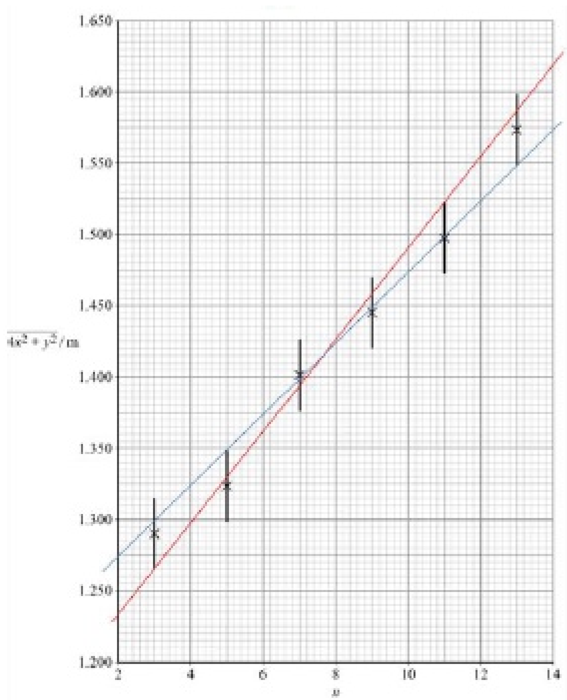
(d) G_{max} line <u>ruled</u> through bottom of *n* = 3 error bar and through top of *n* = 11 error bar 1✓

G_{min} line <u>ruled</u> through top of *n* = 5 error bar and through bottom of *n* = 13 error bar 2 ✓

G_{max} and G_{min} calculated from valid *y* step divided by valid *x* step; <u>both</u> *n* steps ≥ 6 3 ✓

allow 1 mm tolerance when judging intersection of gradient lines with error bars

ignore any unit given with G_{max} or G_{min}; penalise power of ten error in 01.5



12 ✓= 1 MAX if (either) line is thicker than half a grid square or of variable width or not continuous;

expect G_{max} = 3.2(1) × 10^{-2} and G_{min} = 2.5 (2.49) × 10^{-2}

3

(e) $\lambda (\text{from} \frac{G_{max} + G_{min}}{2})$

AND

result in range 2.8(0) to 2.9(0) × 10^{-2} (m) $_1$ ✓ $_2$ ✓

OR

award one mark for

2.7(0) to 3.0(0) × 10^{-2} (m) $_{12}$ ✓

penalise 1 mark for a power of ten error

reject 1 sf 3 × 10^{-2} (m)

if a best fit line is drawn between the G_{max} and G_{min} lines and the gradient of this is calculated award 1 mark for λ in range 2.8(0) to 3.0(0) × 10^{-2}(m)

2

(f) uncertainty in λ = $G_{max} - \lambda$

OR

$\lambda - G_{min}$

OR

$\left(\frac{G_{max} - G_{min}}{2}\right)$ $_1$ ✓

percentage uncertainty = (uncertainty/λ)×100 $_2$ ✓

result in range 11(.0) % to 14(.0) % $_3$ ✓

$_1$✓ can be earned by showing a valid uncertainty then dividing by λ

ecf their λ, G_{max} and G_{min} for $_1$ ✓ and $_2$ ✓

allow λ found from best fit line

accept $\left(\frac{G_{max} - \lambda}{\lambda}\right) \times 100$ or $\left(\frac{G_{max} - G_{min}}{G_{max} + G_{min}}\right) \times 100$ etc for $_{12}$ ✓

allow $\left(\frac{\Delta\lambda}{\lambda}\right)$ × 100 where $\Delta\lambda$ is any plausible uncertainty for $_2$ ✓

numerical answer without valid working can only earn $_3$ ✓

3

(g) (states) calculate the (vertical) intercept 1 ✓

OR

outlines a valid calculation method to calculate *y* 1 ✓

determine the intercept for <u>both lines</u> and calculate average value 2 ✓

OR

determine the (vertical) intercept of the line of best fit (between G_{max} and G_{min}) 2 ✓

draw the line of best fit (between G_{max} and G_{min}); perform calculation to find intercept earns 12 ✓

2

(h)

result	reduced	not affected	increased
G_{max}		✓	
G_{min}	✓		
λ	✓		
y			✓

general marker question

allow any distinguishing mark as long as only one per row

for ✓ and X in same row ignore X

for ✓ and ✓ in same row give no mark

ignore any crossed-out response

4

alternative approach: single best fit line drawn on **Figure 4**

(d) G calculated from y step divided by x step;

n step ≥ 6 3 ✓

MAX 1

(e) λ in range 2.8(0) to 2.9(0) × 10_{-2} ✓

MAX 1

(f) percentage uncertainty in $\lambda = \left(\frac{\Delta\lambda}{\lambda}\right) \times 100$

AND

result in range 11(.0) % to 14(.0) % ✓

MAX 1

(g) calculate intercept

OR

outlines a valid calculation method to find y ✓

MAX 1

(h) as main scheme

no ecf possible

4

alternative approach: non-crossing lines for G_{max} and G_{min} on **Figure 4**:
includes lines that meet but do not cross

(d) G_{max} and G_{min} calculated from y step divided by x step; both n steps ≥ 6 3 ✓

MAX 1

(e) to (h) as main scheme

1

[18]

4. (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]

5. (a) waves are reflected (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]