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GCE AS / A LEVEL – STATIONARY WAVES QUESTION PACK

Legacy PH2 · New spec Unit 2 Topic 5c · AS unit, 20% of A-level

REVISE

.wales

PHYSICS – UNIT 2 · STATIONARY WAVES

PH2.5 Wave properties – stationary waves on strings & in pipes

Formation of stationary waves from superposition of two counter-propagating waves, nodes and antinodes, and harmonics on stretched strings, in air columns and laser cavities.

NEW 2015 SPEC · UNIT 2 TOPIC 5C

Estimated time for entire question pack: ~1 h 52 min

Derived from the legacy PH2 paper's pace of 80 marks in 1¼ hours.

You are advised to **not** attempt to complete all of this in one sitting.

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC PH2 papers (2008 modular spec) that maps onto new-spec Unit 2 Topic 5c (2.5).

Questions are ordered chronologically within each section.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

The number of marks is given in brackets at the end of each question or part-question. A calculator is required.

The Data Booklet is allowed.

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| Q | Source | Max | Mark | Q | Source | Max | Mark |
|--------------|---------------|-----|------|----|---------------|-----------|------|
| 12 | PH2 Jun 15 Q3 | 8 | | 16 | PH2 Jun 10 Q1 | 12 | |
| 13 | PH2 Jun 14 Q1 | 9 | | 17 | PH2 Jun 16 Q2 | 10 | |
| 14 | PH2 Jun 13 Q4 | 10 | | 18 | PH2 Jun 12 Q3 | 8 | |
| 15 | PH2 Jan 10 Q3 | 10 | | 19 | PH2 Jan 12 Q1 | 13 | |
| Total | | | | | | 80 | |

Stationary Waves – what the new spec asks

WJEC GCE AS / A Level Physics (from 2015) · Unit 2: Electricity & Light · Topic 2.5.

Formation A

- Superposition of two waves of equal amplitude and frequency travelling in opposite directions.
- No net energy transport; energy stored in oscillating medium.

Nodes & antinodes A

- Node spacing = $\lambda/2$.
- Antinode spacing = $\lambda/2$ (half a wavelength apart from nodes).
- Phase relationship between points either side of a node.

Strings & pipes A

- Fixed ends (nodes): $f_n = nv/(2L)$.
- Open-pipe: antinodes both ends; closed-pipe: node at closed end.
- Identify harmonics by sketching displacement profiles.

Resonance & cavities A

- Reasoning about a laser cavity: nodes at mirrors; allowed wavelengths $\lambda = 2L/n$.
- Why this gives discrete frequencies, not a continuum.

Stationary Waves in one page

Quick-reference notes – revisit before each section.

Formation

Equal amplitude, equal f , opposite directions.

No net energy transport – energy oscillates between forms.

Nodes & antinodes

Node to node: $\lambda/2$.

Antinode to antinode: $\lambda/2$.

Node to nearest antinode: $\lambda/4$.

Strings (fixed ends)

Boundary: node at each end.

$L = n \times \lambda/2 \Rightarrow f_n = n \times v/(2L)$.

Fundamental: $n = 1$, half a wavelength along L .

Open pipe

$L = n \times \lambda/2$; same formula as string.

Antinode at each open end (open displacement, p.d. zero).

Closed pipe

$L = (2n-1) \times \lambda/4$.

Only odd harmonics: $f_1, 3f_1, 5f_1, \dots$

Cavities

Standing waves between two mirrors of separation L .

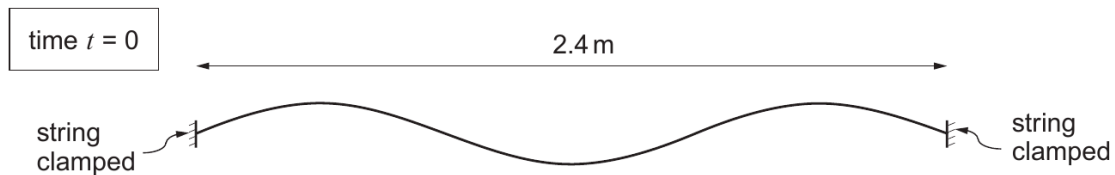
Allowed: $\lambda = 2L/n$ – gives discrete, allowed laser modes.

Section index

Use this index to jump straight to the section you need.

| Section | Questions | Marks |
|--|-----------|----------|
| A Stationary waves on strings & in pipes | Qs 12–19 | 80 marks |

3. (a) The diagram shows a **stationary** wave on a stretched string at a time of maximum displacement ($t = 0$).



- (i) Determine the wavelength. [1]

- (ii) Determine the distances of all the **antinodes** from the left hand end of the string. [1]

- (iii) Time $t = t_1$ is the first time after $t = 0$ that the string is as shown below.



- (I) The frequency is 50 Hz. Determine t_1 . [2]

- (II) **On the diagram** for time $t = t_1$, draw vertical arrows at the approximate positions of the antinodes, to show the directions of motion of the string. [1]

- (b) Complete the diagram below to show the lowest frequency (fundamental) stationary wave on the string, at a time of maximum displacement, and **calculate its frequency**. [3]



Answer **all** questions.

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1. (a) A string is stretched between fixed points **A** and **B**.



A stationary wave is set up on the string. The nodes are at the points marked by dots.

- (i) At one instant the string is straight, as shown. Point **P** is moving upwards. **Add to the diagram** a sketch of the string a quarter of a cycle later. [1]
- (ii) Compare the phases and amplitudes of the wave at points **P** and **Q**. [2]

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- (iii) Compare the phases and amplitudes of the wave at points **Q** and **R** (which are equal distances either side of a node). [2]

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- (iv) The string is 0.60 m long and vibrates at a frequency of 240 Hz. Calculate the wave speed, giving your reasoning. [2]

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(b) A new stationary wave with a different frequency is set up on the same string. The nodes are as shown.

Examiner only



Calculate the new wave frequency, showing your working.

[2]

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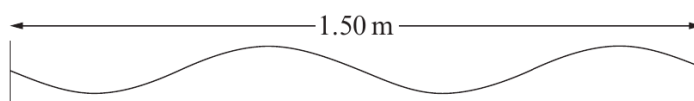
4. (a) Explain how a stationary wave can be regarded as being formed from progressive waves. [2]

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- (b) A string, fixed at both ends, vibrates in a stationary wave pattern. The diagram shows the string at a time of maximum displacement.



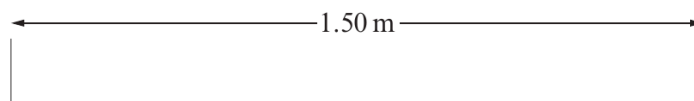
- (i) On the same diagram, **draw** the string
- (I) a quarter of a cycle later [label the drawing 'I'], [1]
- (II) half of a cycle later [label the drawing 'II']. [1]
- (ii) The speed, v , of the progressive waves on the string is 96 ms^{-1} . Calculate the frequency of the stationary wave. [2]

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- (c) (i) Sketch the string at its maximum displacement when it is vibrating in a stationary wave with a single antinode. [1]



- (ii) Calculate the frequency of vibration. [2]

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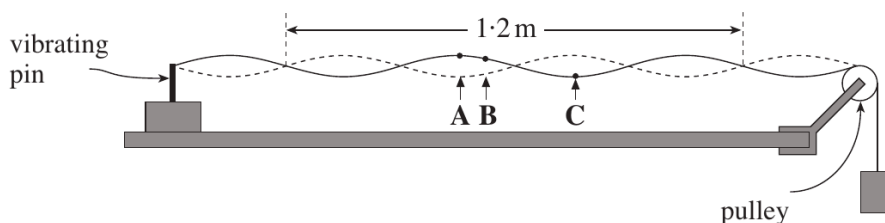
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- (d) Write down an equation which gives the frequency of a stationary wave on this string when it is vibrating with a total of n antinodes. [1]

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3. The diagram shows a demonstration of a *stationary wave* on a string.



(a) (i) State whether the following pairs of points on the string are vibrating *in phase*, *in antiphase*, or neither in phase nor in antiphase. [2]

A and B

A and C

(ii) Describe briefly how you could check this experimentally. [2]

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(b) (i) Progressive waves transfer energy through the medium; stationary waves do not do this. Describe **one** other difference between progressive and stationary waves. [2]

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(ii) Explain how, in the set-up above, the stationary wave can be thought of as arising from progressive waves. [2]

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(c) (i) From the diagram deduce a value for the wavelength. [1]

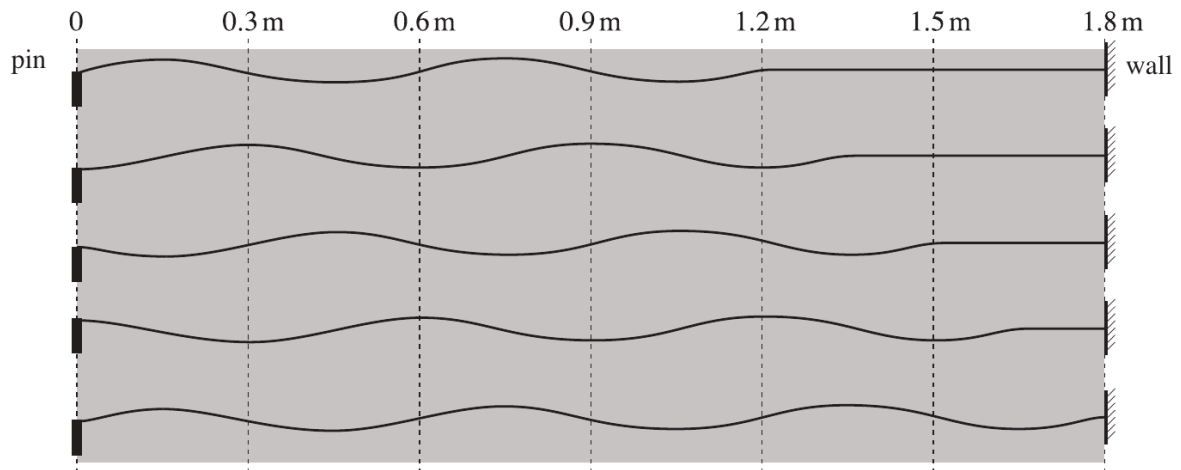
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(ii) The pin is vibrating at a frequency of 50 Hz. Calculate the wave speed. [1]

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1. A piece of string 1.8 m long is attached at one end to the pin of a vibration generator and, at the other end, to a rigid wall. The diagrams show the string at intervals of 0.0030 s, starting from shortly after the generator has been connected to the signal generator (so the wave has not yet reached the wall).



(a) Calculate

- (i) the *speed* of the waves, [2]

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- (ii) the *frequency*. [3]

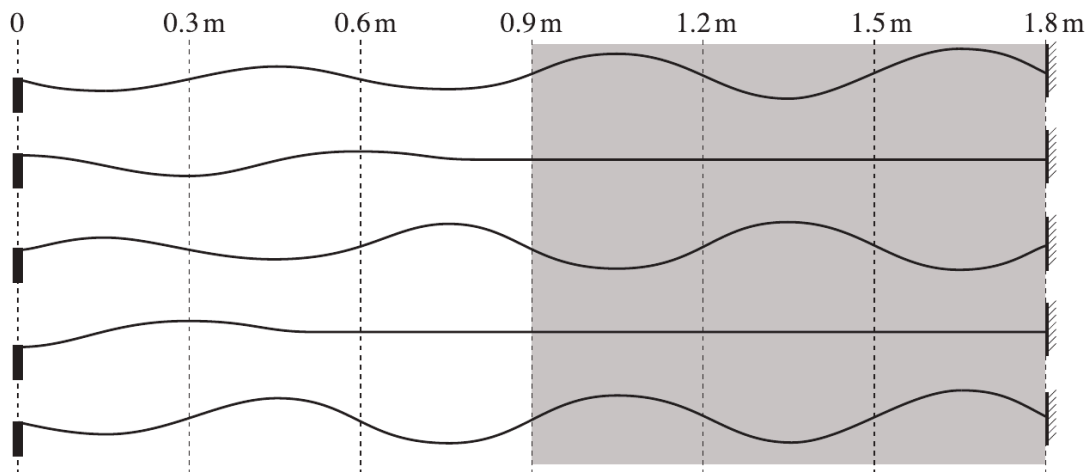
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(b) Later on a *stationary wave* develops. Refer to the shaded area below.



(i) Write down two distances from the generator at which there are *nodes*. [1]

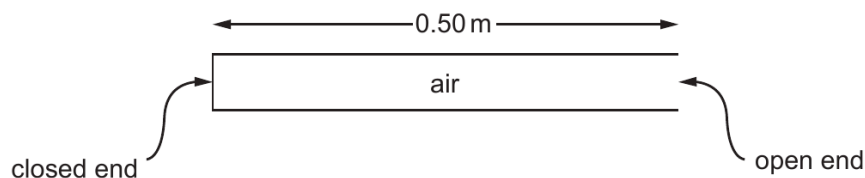
(ii) (I) Describe how the *amplitude* of the stationary wave varies with distance along the string. [2]

(II) Explain whether or not the same description applies to the amplitude of the *progressive wave* (see previous page). [1]

(c) Explain in terms of *interference* how the stationary wave is formed and, in particular, how *nodes* arise. [3]

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2. (a) A stationary sound wave is set up in air in the tube shown in the diagram. The speed of sound in the air is 342 m s^{-1} .



- (i) There is an antinode of displacement at the open end of the tube, and a node at the closed end. Calculate the lowest frequency possible for the stationary wave. [2]

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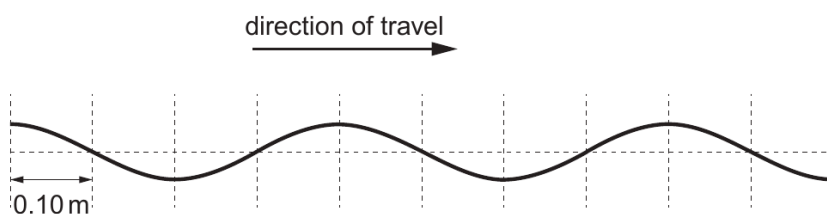
- (ii) The wave speed given above is for progressive waves. Explain how the stationary wave arises from progressive waves. [2]

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- (b) Waves are travelling to the right along a taut string at a speed of 5.0 m s^{-1} . The diagram shows part of the string at time $t = 0$.



- (i) **On the same diagram**, draw this part of the string at time $t = 0.10 \text{ s}$. [2]

- (ii) Calculate the frequency. [2]

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- (iii) The wave source (not shown) is now adjusted to increase the frequency. Explain the effect that this will have on the wavelength, stating any assumption that you make. [2]

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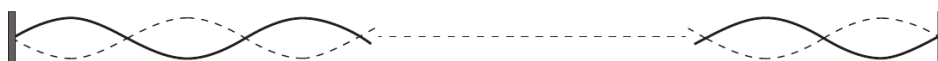
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3. The cavity of a laser has reflecting ends a distance L apart. Assuming there is a node at each end, the possible wavelengths of stationary waves are given by the equation

$$\lambda = \frac{2L}{n} \quad \text{in which } n \text{ is a whole number.}$$

- (a) Label relevant lengths on the diagram, and hence show how this equation arises. [The stationary wave is shown as if it were a stationary wave on a stretched string.] [2]



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- (b) For a particular semiconductor laser, $L = 0.2050$ mm.
- (i) Using the equation above, show that a stationary wave of wavelength 820.0 nm can exist in the cavity, but that a stationary wave of wavelength 821.0 nm cannot. [2]

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- (ii) Find the next wavelength above 820.0 nm of stationary wave that could exist in the cavity. [2]

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- (c) A stationary wave is equivalent to a superposition of progressive waves of equal amplitude travelling in opposite directions. Why is this condition not exactly met in a laser emitting a beam of light? [2]

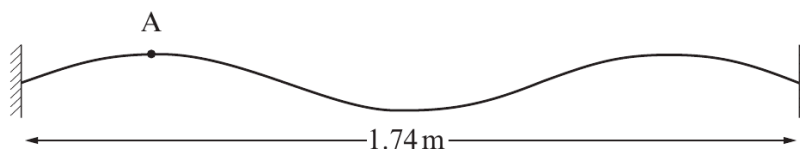
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1. (a) A string is stretched between two fixed supports, 1.74 m apart, and is set vibrating in a stationary wave with a periodic time of 0.020 s.

The diagram shows the string at time $t = 0$, when its displacement is at a maximum.



- (i) **On the same diagram** draw the string at times
- (I) $t = 0.010$ s, [Label it 'I'.] [1]
 - (II) $t = 0.015$ s. [Label it 'II'.] [1]
- (ii) Show that the speed of waves in the string is approximately 60 ms^{-1} . [3]

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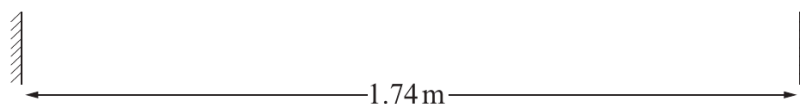
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- (iii) Use 'N' to show on the diagram the positions of **all** nodes. [1]
- (iv) Use crosses to mark on the diagram two points on the string which are vibrating *in phase* with point A on the string. **One of your crosses must be on the left hand half of the string, the other on the right hand half.** [1]

- (b) (i) Show the lowest frequency mode of vibration of the same string, by drawing the string (at a time of maximum displacement) in the diagram below. [1]



- (ii) Calculate this lowest frequency, giving your reasoning. [2]

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(c) (i) State the *Principle of Superposition*. [1]

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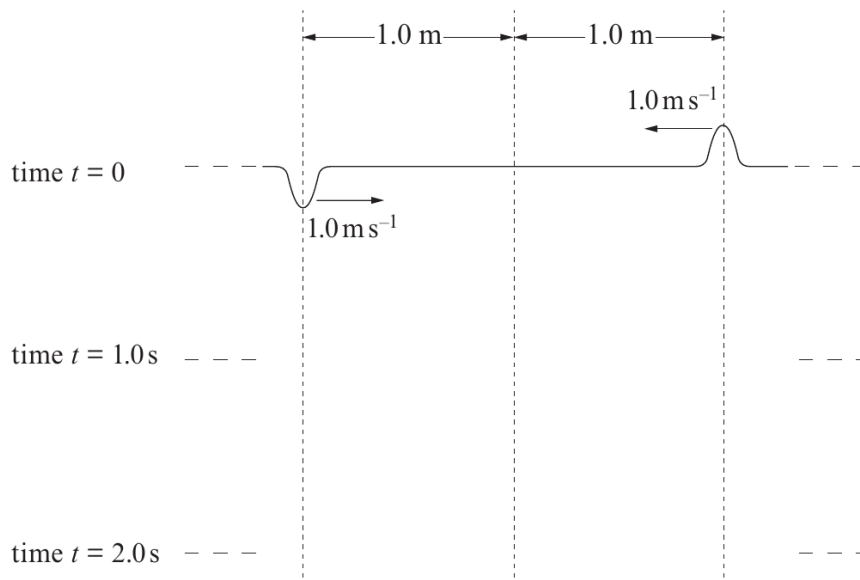
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(ii) Waves in the form of single pulses are sent along a string from both ends, and travel in opposite directions at a speed of 1.0 ms^{-1} .

At time $t = 0$, the pulses are 2.0 m apart, as shown below in the top diagram.

In the labelled gaps directly below this diagram, sketch the string at times of 1.0 s and 2.0 s . [2]



END OF QUESTION PACK

8 questions · 80 marks · ~1 h 52 min

Source: WJEC PH2 (2008 modular spec)

Curated for WJEC Physics 2015 spec AS Unit 2 – Topic 5c (2.5)

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