InkPhysics

ANSWER BOOK

Stationary waves

Waves · Year 12

AQA 3.3.1.3 · CIE 8.1.1, 8.1.2, 8.1.3, 8.1.4
OCR A 4.4.3(a)(i), 4.4.3(b), 4.4.4(a), 4.4.4(b), 4.4.4(c), 4.4.4(d), 4.4.4(e)(i), 4.4.4(e)(ii), 4.4.4(f), 4.4.4(g)

19 questions · 55 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Two progressive waves of the same frequency and amplitude travel in opposite directions (for example an incident wave and its reflection) and superpose (1), producing a pattern of nodes and antinodes that does not move along the string (1). [2]

A2 Half a wavelength, $\lambda/2$ (1). [1]

A3 A node is a point of zero amplitude (no displacement) (1); an antinode is a point of maximum amplitude (1). [2]

A4 T is the tension in the string (1). μ is the mass per unit length of the string, measured in kg m^{-1} (1). [2]

A5 The ends are fixed and cannot move, so their displacement is always zero, which is the definition of a node (1). [1]

A6 P and Q: zero, they oscillate in phase (1). P and R: π rad (180°), they oscillate in antiphase (1). [2]

SECTION B · Standard

B1 (a) Fundamental: $\lambda = 2L = 2 \times 0.60 = 1.2$ m (1) [3]
(b) $f = v/\lambda = 240/1.2$ (1)
$f = 200$ Hz (1)

B2 Second harmonic: $\lambda = L = 0.60$ m (1) [3]
$f = 240/0.60 = 400$ Hz (1)
Third harmonic: $f = 3v/2L = 600$ Hz (1)

B3 Fundamental: $\lambda = 2L = 1.6$ m (1) [3]
$v = f\lambda = 150 \times 1.6$ (1)
$v = 240$ m s^{-1} (1)

B4 Node to node = $\lambda/2$ (1) [3]
= 0.25 m (1)
Node to antinode = $\lambda/4 = 0.125$ m (1)

B5 μ = mass/length = $(1.20 \times 10^{-3})/0.750 = 1.60 \times 10^{-3}$ kg m^{-1} (1). $f_1 = (1/(2 \times 0.750)) \times \sqrt{(90.0/(1.60 \times 10^{-3}))}$ (1) = 158 Hz (1). [3]

B6 $f_1 \propto \sqrt{T}$ when L and μ are constant (1), so doubling f_1 requires the tension to increase by a factor of 4 (1). [2]

B7 5 nodes, counting the two fixed ends (1), and 4 antinodes (1). $\lambda = 2L/n = (2 \times 1.2)/4 = 0.60$ m (1). [3]

SECTION C · Stretch

C1 Fundamental: $\lambda = 2L = 2.4$ m (1) [4]
$f_1 = v/2L = 180/2.4 = 75$ Hz (1)
Harmonics are multiples of f_1 (1)
75 Hz, 150 Hz, 225 Hz (1)

C2 $\lambda = v/f = 200/300$ (1) [4]
$\lambda = 0.667$ m (1)
Number of half-wavelengths $n = 2L/\lambda = 2 \times 1.0/0.667$ (1)
n = 3, so it is the third harmonic (1)

C3 1. A progressive wave transfers energy along its path; a stationary wave transfers no net energy (1). 2. In a progressive wave every particle has the same amplitude; in a stationary wave the amplitude varies from zero at nodes to a maximum at antinodes (1). 3. In a progressive wave the phase varies continuously with position; in a stationary wave all particles between adjacent nodes oscillate in phase (1). [3]

C4 $\mu = 0.60$ g m^{-1} = 6.0×10^{-4} kg m^{-1} (1). $f_1 = (1/(2 \times 0.328)) \times \sqrt{(50.0/(6.0 \times 10^{-4}))}$ (1) = 440 Hz (1). This matches 440 Hz, so the maker's statement is correct (1). [4]

C5 Adjacent harmonics differ by f_1, since $f_n = nf_1$ (1), so $f_1 = 300 - 240 = 60$ Hz (1). For the first harmonic $\lambda = 2L = 3.0$ m (1). $v = f_1\lambda = 60 \times 3.0 = 180$ m s^{-1} (1). [4]

C6 Stretch the string from a vibration generator (driven by a signal generator) over a pulley to hanging masses, so the tension stays constant throughout (1). Adjust the driving frequency until the string vibrates in a single loop, the first harmonic, with a node at each end and one antinode at the centre (1). Record the frequency from the signal generator and measure the vibrating length L with a metre rule (1). Repeat for a range of different lengths, keeping the same string and the same tension (1). Plot f_1 against 1/L (1). A straight line through the origin shows $f_1 \propto 1/L$ (1). [6]