

## C.4 Standing waves and resonance

Practice Worksheet — name: \_\_\_\_\_ date: \_\_\_\_\_

### FORMULAS FOR THIS TOPIC

HARMONICS (STRING / OPEN-OPEN PIPE)  $f_n = \frac{nv}{2L}$  HARMONICS (CLOSED-OPEN PIPE)  $f_n = \frac{nv}{4L}$ ,  $n = 1, 3, 5, \dots$ 

### SECTION A — MULTIPLE CHOICE

A1. At a node of a standing wave:

- A The amplitude is maximum and energy is transferred
- B The displacement is always zero
- C The particles oscillate with maximum speed
- D The wave changes phase by  $90^\circ$

A2. A pipe closed at one end resonates at a fundamental frequency of 85 Hz. Its next resonant frequency is:

- A 170 Hz
- B 255 Hz
- C 340 Hz
- D 425 Hz

A3. Two points on a standing wave separated by one node oscillate:

- A In phase with equal amplitudes
- B In antiphase, generally with different amplitudes
- C  $90^\circ$  out of phase
- D In phase, generally with different amplitudes

### SECTION B — SHORT ANSWER

B1. A string of length 0.60 m fixed at both ends produces a second harmonic of 440 Hz. Calculate the wave speed on the string. [3 marks]

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**B2.** State three differences between a standing wave and a travelling wave. [3 marks]

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**B3.** A washing machine vibrates violently at one particular spin speed but is quieter above and below it. Explain this observation and suggest how the effect is reduced in practice. [3 marks]

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## ANSWER KEY

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### Section A

**A1:** The displacement is always zero — Nodes are points of permanent destructive interference between the two travelling waves, so the displacement there is zero at all times. Antinodes, midway between nodes, oscillate with maximum amplitude.

**A2:** 255 Hz — A closed–open pipe supports only odd harmonics:  $f_n = nf_1$  with  $n = 1, 3, 5, \dots$ . The next mode after 85 Hz is  $3 \times 85 = 255$  Hz — the missing even harmonics give clarinets their hollow timbre.

**A3:** In antiphase, generally with different amplitudes — Crossing a node flips the phase by  $180^\circ$ : when one side moves up, the other moves down. Amplitude depends on distance from the node, so it generally differs between the two points.

### Section B

**B1:** Second harmonic:  $\lambda = L = 0.60$  m. Then  $v = f\lambda = 440 \times 0.60 = 264$  m s<sup>-1</sup>. (Equivalently  $f_n = nv/2L$  with  $n = 2$ .)

**B2:** A standing wave transfers no energy (it stores it), a travelling wave transports energy; standing-wave amplitude varies with position (zero at nodes, maximum at antinodes) while a travelling wave has the same amplitude everywhere; in a standing wave all points between adjacent nodes oscillate in phase, whereas in a travelling wave the phase varies continuously along the wave.

**B3:** At that spin speed the drum's rotation frequency matches a natural frequency of the machine — resonance — so energy is transferred efficiently and the amplitude peaks. Above and below, driver and natural frequency mismatch and the response is small. Manufacturers add damping (rubber mounts, friction dampers), which lowers and broadens the resonance peak.