2.1 Wave quantities and graphs

Name: _____ Class: _____ Date: _____ **Total: 21 marks**

KEY WORDS amplitude • Equilibrium • period • frequency • wavelength • wave speed • transverse wave • longitudinal wave • compressions • rarefactions

Objective

Build the methods for WPH12 statements 33–37: wave quantities and graphs. These are original teaching questions, not copied past-paper items.

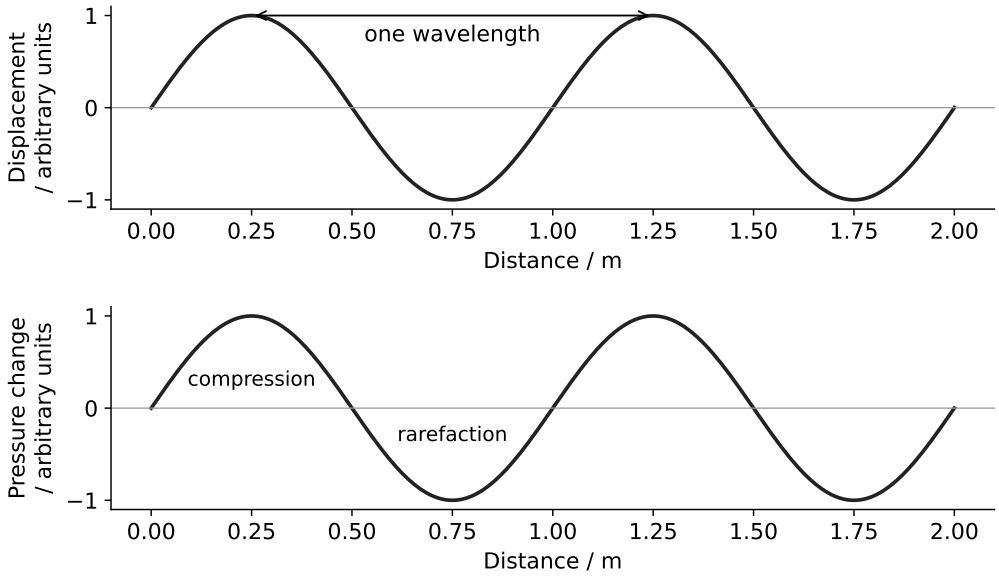
1 Key knowledge and worked examples

A vibrating source repeats its motion. The **amplitude** is the greatest displacement from equilibrium. **Equilibrium** means the resting position. The **period** T is the time for one complete vibration. The **frequency** f is the number of complete vibrations each second; its unit is hertz, Hz.

$$f = \frac{1}{T} \qquad v = f\lambda$$

The **wavelength** λ is the distance between nearest points vibrating in phase. The **wave speed** v is the speed at which a fixed phase, such as a crest, travels. It is not the speed of a vibrating particle.

- A **transverse wave** has vibrations perpendicular to its direction of travel. A rope moves up and down while its disturbance travels along the rope.
- A **longitudinal wave** has vibrations parallel to its direction of travel. Sound has **compressions**, where pressure and density are higher, and **rarefactions**, where they are lower.
- Air molecules move back and forth about their resting positions. They do not travel from the speaker to your ear with the sound.



Distance graphs show a whole wave at one instant.

Read the horizontal axis first

A displacement–distance graph is a snapshot. The separation of neighbouring crests gives λ. A displacement–time graph follows one particle. The separation of neighbouring peaks gives T. The same curve shape can represent either graph, but the quantities are different.

For a longitudinal wave, a pressure–distance graph shows compressions at pressure maxima. A molecular displacement–distance graph shows displacement along the direction of travel. Maximum compression occurs where displacement changes most rapidly towards the neighbouring molecules. Pressure maximum and displacement maximum are not at the same place; their patterns are one-quarter wavelength apart in a sinusoidal travelling sound wave.

Worked example. A microphone records 12 complete cycles in 0.030 s. Sound travels at 340 m s^{-1}. Find its frequency and wavelength.

- Known: cycle count, total time and speed. Frequency counts cycles per second; the wave equation then links speed to wavelength.

$$f = \frac{N}{t} = \frac{12}{0.030\ \text{s}} = 400\ \text{Hz}$$

$$v = f\lambda \quad \Rightarrow \quad \lambda = \frac{v}{f} = \frac{340\ \text{m s}^{-1}}{400\ \text{Hz}} = 0.85\ \text{m}$$

- Check: one cycle takes $T = 1/f = 0.0025$ s. Twelve cycles take the stated 0.030 s.

■ Standing sound in a closed tube

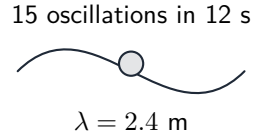
In the simplest standing sound wave in a tube closed at one end, the closed end is a molecular displacement node. The open end is approximately a displacement antinode. This fits one-quarter wavelength into the effective tube length, so $L_{effective} = \lambda/4$. The pressure pattern is reversed: the closed end is a pressure antinode. Do not call a pressure node a displacement node. Real tubes have a small open-end correction; use an effective length if the question supplies it.

Worked example. A closed tube has effective length 0.20 m and fundamental frequency 425 Hz. The end conditions give $\lambda = 4L = 0.80$ m; then $v = f\lambda = 425 \times 0.80 = 340$ m s^{-1}. A string fixed at both ends instead fits half a wavelength in its fundamental. Choose from the end conditions, not from the word "standing".

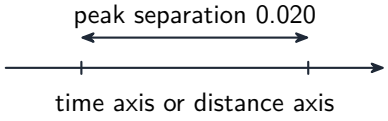
2 Practice

2.1 State the meanings of amplitude and period. [2]

2.2 A buoy completes 15 oscillations in 12 s. The water-wave wavelength is 2.4 m. Calculate frequency, period and wave speed. [3]

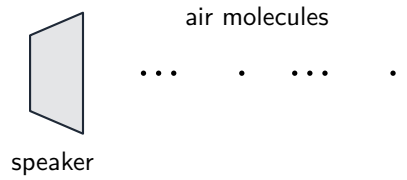


2.3 A displacement graph has neighbouring peaks separated horizontally by 0.020. Explain what this separation gives if the horizontal axis is (a) time in seconds; (b) distance in metres. State why the graph shape alone is not enough. [3]



3 Exam-style questions

3.1 A loudspeaker sends sound through still air. Describe the direction of molecular motion, the motion of the disturbance, and the pressure at a compression. Explain why a pressure maximum is not a maximum molecular displacement. [4]



3.2 A time trace shows 8.0 complete sound cycles across 4.0 horizontal divisions. The time base is 0.50 ms per division. Sound speed is 340 m s^{-1}. Calculate the period, frequency and wavelength. A student calls the trace a picture of the wavelength. Explain the mistake. [5]

8 cycles / 4 divisions
0.50 ms per division

$v = 340$ m/s

3.3 Sketch displacement against distance for a transverse wave of amplitude 2.0 cm and wavelength 0.60 m. Label both axes and show two complete wavelengths. Explain what a point on this curve represents. [4]