

OCR A AS Wave Motion 1 Progressive Waves and Wave Quantities solutions

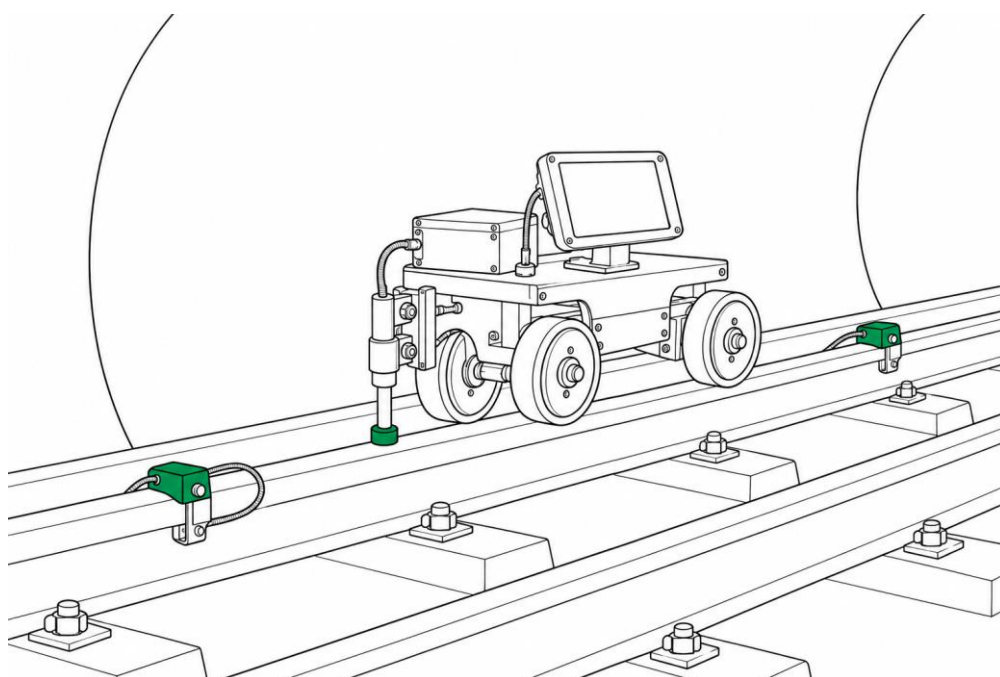
Matching solutions and teaching prompts for the class review

Specification points covered

- 4.4.1(a) Define and describe progressive, longitudinal and transverse waves.
- 4.4.1(b)(i) Define displacement, amplitude, wavelength, period, phase difference, frequency and wave speed.
- 4.4.1(b)(ii) Use an oscilloscope to determine frequency and wave characteristics.
- 4.4.1(c) Use $f = 1/T$ to relate frequency and period.
- 4.4.1(d) Use the wave equation $v = f\lambda$.
- 4.4.1(e) Interpret graphs of transverse and longitudinal waves.

Teaching focus

Require pupils to state what the horizontal axis represents before reading wavelength, period or phase difference.
For wave types, insist on vibrations being parallel or perpendicular to the direction of wave travel or energy transfer.



Context diagram: an ultrasonic rail-tunnel inspection trolley and its vibration sensors.

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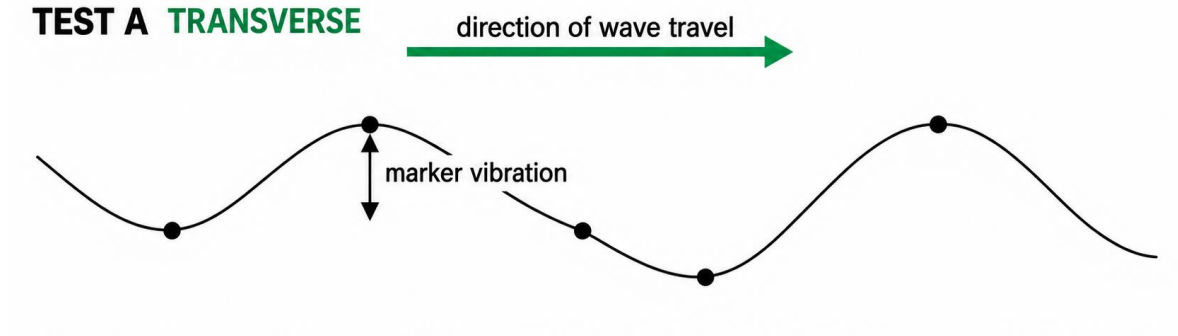
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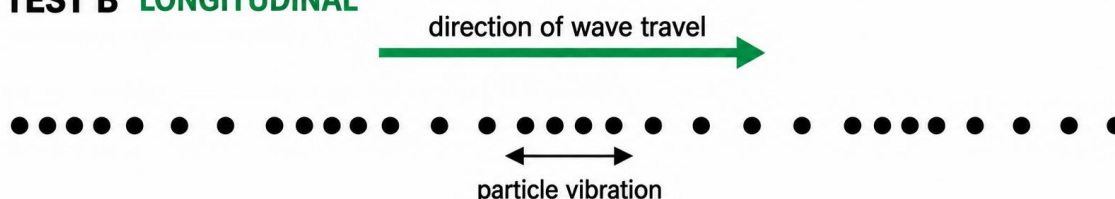
1 Recognising progressive waves

1. The diagram shows two wave tests used by the tunnel engineers. For each test, identify whether the wave is transverse or longitudinal and describe the direction of the local vibration relative to the direction of wave travel. [4 marks]

TEST A TRANSVERSE



TEST B LONGITUDINAL



Solution diagram: Test A is transverse and Test B is longitudinal.

Answer / mark points: Test A is transverse: the marker vibrates perpendicular to the direction of wave travel or energy transfer. Test B is longitudinal: the particles vibrate parallel to the direction of wave travel or energy transfer.

Teacher prompt / common error: Use vibrations or oscillations, not the movement of the whole wave. Compare each vibration direction with energy transfer.

2. A marker on the inspection cable oscillates as a pulse passes, but remains near its original position afterwards. Explain why the pulse is a progressive wave and distinguish the transfer of energy from the motion of the cable material. [2 marks]

Answer / mark points: A progressive wave transfers energy from one position to another. The cable elements oscillate about their equilibrium positions, so there is no net transfer of the cable material with the wave.

Teacher prompt / common error: A progressive wave transports energy; particles of the medium oscillate but do not travel with the disturbance.

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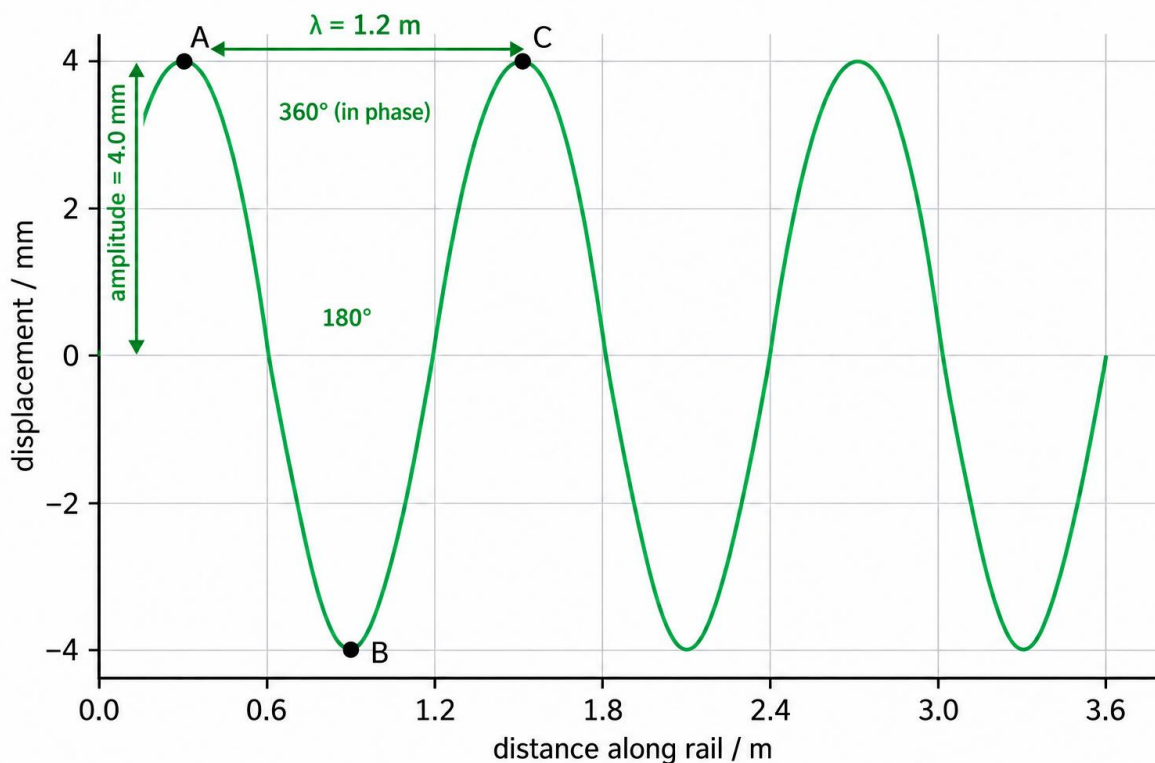
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2 Reading a displacement-distance graph

3. For the rail wave shown, define displacement and amplitude. [2 marks]



Solution graph: amplitude 4.0 mm, wavelength 1.2 m; A and B are 180° apart, while A and C are in phase.

Answer / mark points: Displacement is the distance and direction of a point on the rail from its equilibrium position. Amplitude is the maximum magnitude of that displacement.

Teacher prompt / common error: Displacement includes direction from equilibrium. Amplitude is the maximum magnitude, not the crest-to-trough distance.

4. Use the graph to state the amplitude and wavelength of the rail wave. [2 marks]

Answer / mark points: Amplitude = 4.0 mm. Wavelength = distance between adjacent points in phase, such as consecutive crests = 1.2 m.

Teacher prompt / common error: Read wavelength horizontally between adjacent points at the same stage of the cycle.

5. Determine the phase difference between A and B and between A and C. State whether A and C are in phase. [2 marks]

Answer / mark points: A to B is half a wavelength, so the phase difference is 180° or π rad. A to C is one wavelength, so the phase difference is 360° or 2π rad, equivalent to 0°; A and C are in phase.

Teacher prompt / common error: Half a wavelength corresponds to 180°. One full wavelength corresponds to 360°, which is equivalent to zero phase difference.

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3 Calculating wave quantities

6. The wave travels through the rail at $5.10 \times 10^3 \text{ m s}^{-1}$. Calculate its frequency. [1 mark]

Answer / mark points: $f = v/\lambda = (5.10 \times 10^3)/1.2 = 4.25 \times 10^3 \text{ Hz} = 4.25 \text{ kHz}$.

Teacher prompt / common error: Use the spatial wavelength from the graph in $v = f\lambda$. No unit conversion is needed for metres.

7. Use your answer to Question 6 to calculate the period of the wave and the time taken for a point on the rail to move from a crest to the next trough. [2 marks]

Answer / mark points: $T = 1/f = 1/(4.25 \times 10^3) = 2.35 \times 10^{-4} \text{ s}$. Crest to next trough is half a cycle, so $t = T/2 = 1.18 \times 10^{-4} \text{ s}$.

Teacher prompt / common error: The period is the time for one complete cycle. Crest to trough is half a period, not a full period.

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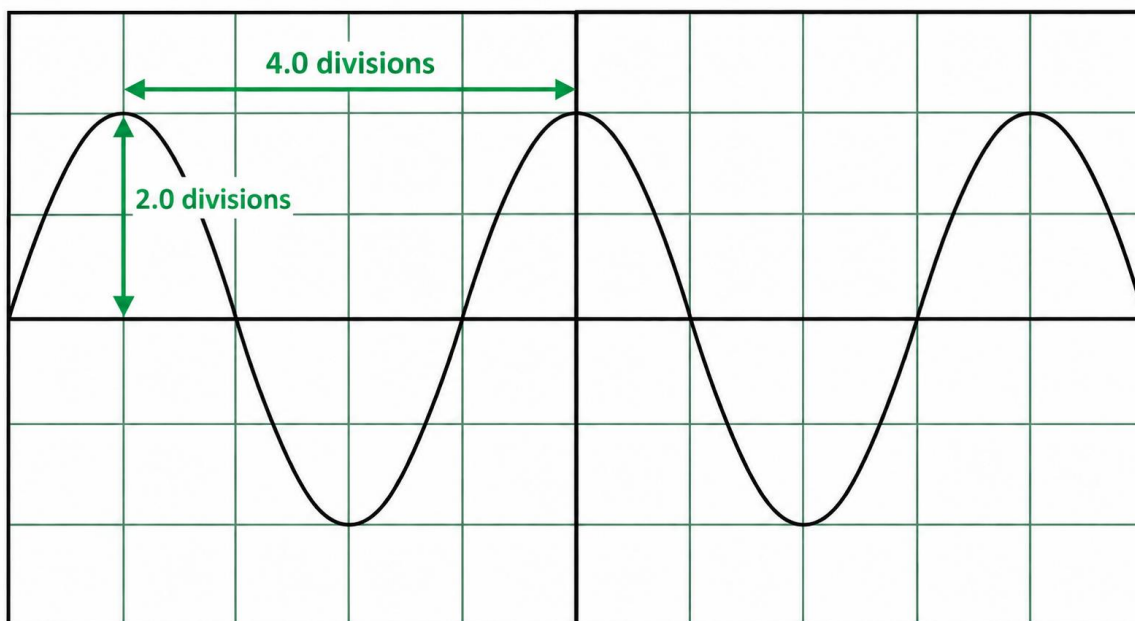
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4 Reading an oscilloscope

8. The oscilloscope y-sensitivity is 0.50 V div^{-1} . Determine the peak voltage of the signal. [1 mark]



Solution trace: amplitude 2.0 divisions and period 4.0 divisions.

Answer / mark points: Peak voltage = $2.0 \text{ div} \times 0.50 \text{ V div}^{-1} = 1.0 \text{ V}$.

Teacher prompt / common error: Measure from the centre line to a crest. Do not use the peak-to-peak height.

9. The oscilloscope time-base is 0.20 ms div^{-1} . Determine the period and frequency of the signal. [2 marks]

Answer / mark points: $T = 4.0 \text{ div} \times 0.20 \text{ ms div}^{-1} = 0.80 \text{ ms} = 8.0 \times 10^{-4} \text{ s}$. $f = 1/T = 1.25 \times 10^3 \text{ Hz} = 1.25 \text{ kHz}$.

Teacher prompt / common error: The period is crest-to-crest: four horizontal divisions. Convert milliseconds to seconds before taking the reciprocal.

10. The time-base is changed to 0.10 ms div^{-1} without changing the signal. Calculate how many cycles would be displayed across the ten-division screen width. [2 marks]

Answer / mark points: Displayed time = $10 \text{ div} \times 0.10 \text{ ms div}^{-1} = 1.0 \text{ ms}$. Number of cycles = $1.0/0.80 = 1.25$ cycles.

Teacher prompt / common error: Changing the time-base changes the amount of time shown, not the signal period.

11. Describe how an engineer should use several cycles on an oscilloscope trace to obtain a reliable value for the signal frequency. [2 marks]

Answer / mark points: Measure the horizontal width of several complete cycles, convert the divisions to a total time using the time-base, and divide by the number of cycles to obtain the mean period. Then calculate $f = 1/T$. Using several cycles reduces the percentage uncertainty in reading the screen.

Teacher prompt / common error: Measuring several cycles reduces the fractional reading uncertainty. Divide the total time by the number of cycles before using $f = 1/T$.

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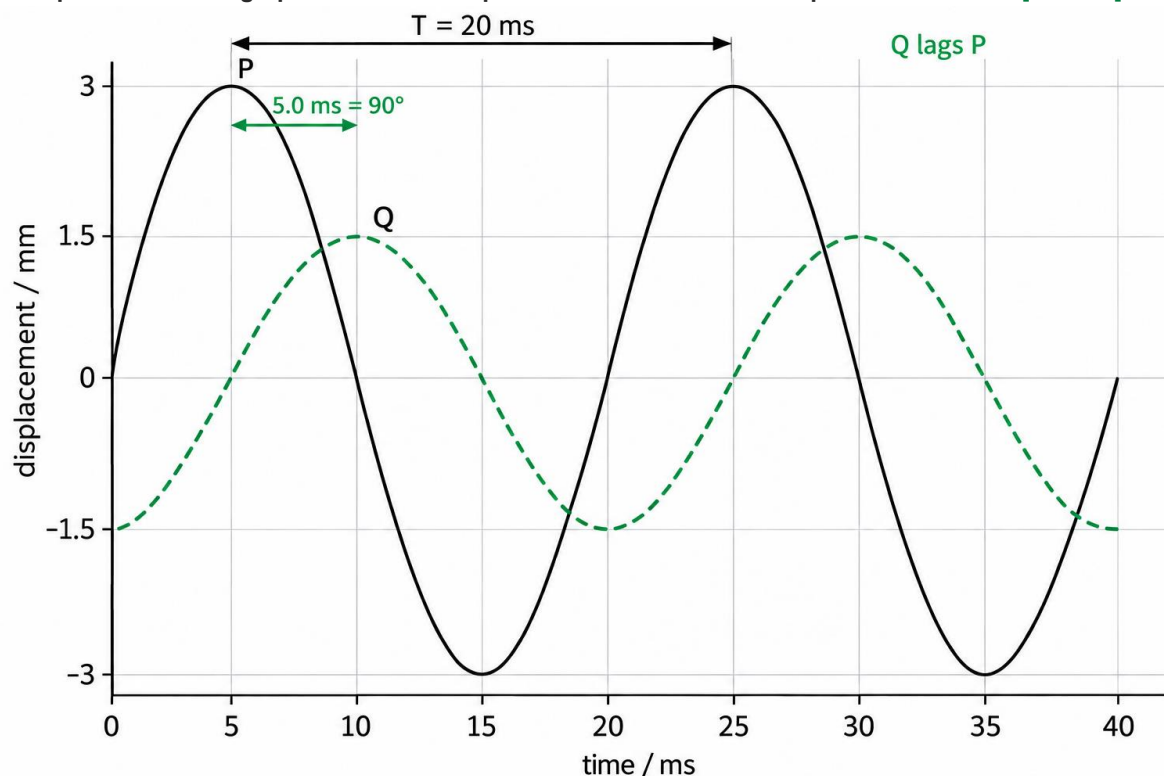
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5 Comparing sensor traces

12. Use the displacement-time graph to state the amplitude of trace P and the amplitude of trace Q. [2 marks]



Solution graph: $T = 20$ ms and Q lags P by 5.0 ms, equivalent to 90° .

Answer / mark points: Amplitude of P = 3.0 mm. Amplitude of Q = 1.5 mm.

Teacher prompt / common error: Amplitude is measured vertically from the zero-displacement line to a crest or trough.

13. Determine the period and frequency of the oscillations shown. [2 marks]

Answer / mark points: The interval between successive crests of P is 20 ms, so $T = 20$ ms = 0.020 s. $f = 1/T = 50$ Hz.

Teacher prompt / common error: Use the time between corresponding points on one trace, not the separation between P and Q.

14. Determine the phase difference between P and Q. State which trace lags the other. [2 marks]

Answer / mark points: The corresponding crest of Q occurs 5.0 ms after the crest of P. Phase difference = $(5.0/20) \times 360^\circ = 90^\circ$ or $\pi/2$ rad. Q lags P.

Teacher prompt / common error: Compare corresponding crests. Q reaches the crest later, so Q lags P.

15. Explain why this is a displacement-time graph and why wavelength cannot be determined from this graph alone. [2 marks]

Answer / mark points: Each trace shows how displacement at one sensor position changes as time passes, so the horizontal axis is time. Wavelength is a spatial separation between adjacent points in phase; a distance graph or the wave speed together with frequency is needed to determine it.

Teacher prompt / common error: A time graph follows one position. A distance graph shows many positions at one instant.

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6 Applying wave measurements

16. Two sensors on the same rail are 3.00 m apart. A pulse reaches sensor A at 1.20 ms and sensor B at 1.79 ms. Calculate the speed of the pulse between the sensors. [2 marks]

Answer / mark points: $\Delta t = 1.79 \text{ ms} - 1.20 \text{ ms} = 0.59 \text{ ms} = 5.9 \times 10^{-4} \text{ s}$. $v = 3.00 / (5.9 \times 10^{-4}) = 5.08 \times 10^3 \text{ m s}^{-1}$, which is about $5.1 \times 10^3 \text{ m s}^{-1}$.

Teacher prompt / common error: Use the difference between arrival times, not either clock reading by itself. Convert milliseconds to seconds.

17. The ultrasonic transmitter operates at 75.0 kHz. Use the speed from Question 16 to calculate the wavelength in the undamaged rail. [2 marks]

Answer / mark points: $\lambda = v/f = (5.08 \times 10^3) / (75.0 \times 10^3) = 6.78 \times 10^{-2} \text{ m} = 0.0678 \text{ m}$.

Teacher prompt / common error: Convert kilohertz to hertz before using $v = f\lambda$.

18. In a damaged section of rail the wave speed is $4.50 \times 10^3 \text{ m s}^{-1}$ while the transmitter frequency remains 75.0 kHz. Explain why the frequency remains unchanged and calculate the wavelength in the damaged section. [3 marks]

Answer / mark points: The transmitter fixes the rate at which oscillations are produced, so crossing into a different section changes speed and wavelength but not frequency. $\lambda = v/f = (4.50 \times 10^3) / (75.0 \times 10^3) = 6.00 \times 10^{-2} \text{ m} = 0.0600 \text{ m}$.

Teacher prompt / common error: Frequency is set by the source. A lower speed at unchanged frequency produces a shorter wavelength.

Language and method check

A wave travels or transfers energy; a particle of the medium oscillates about an equilibrium position.

Amplitude is the maximum magnitude of displacement, not the peak-to-peak value.

Points separated by a whole number of wavelengths are in phase; points separated by half a wavelength are in antiphase.

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