

Wave speed frequency and wavelength

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Paper 2 | Foundation and Higher

Worked solutions and teaching prompts | 30 core parts + 2 Physics-only parts | 57 marks total

Specification points covered

Transverse and longitudinal waves; energy transfer without net movement of the medium: 8463 4.6.1.1; 8464 6.6.1.1

Amplitude, wavelength, frequency, period and wave speed; sound/ripple measurement: 8463 4.6.1.2; 8464 6.6.1.2

Waves in a liquid and a solid: 8463 required practical 8; 8464 required practical 20

Separate Physics only: sound speed, frequency and wavelength on changing medium within 4.6.1.2

A harbour team tests a wave-warning system. A camera records the water surface and a fixed buoy records vertical displacement. Engineers also test a sensor cable, model water waves in a ripple tank and check an air-horn signal. Treat the harbour waves as regular idealised waves; the warning rule is for this exercise only.

Shared core for both routes and tiers. Question 7 is Separate Physics only, NOT Higher-only. Accept equivalent wording and consistent follow-through. Suggested timing is not classroom-tested and excludes Question 7. This original PhysicsUK resource is not an official AQA paper or mark scheme.

1 Checking the wave calculations

Each part uses a separate test. Show working and units.

1(a) In the school model, a water-surface marker moves up and down while ripples travel horizontally. Identify the wave type and explain your choice. **[2 marks]**

Answer / mark points: Transverse. [1] The marker oscillates perpendicular to the direction of wave travel / energy transfer. [1]

Teacher prompt: Use the relative directions, not just “the wave goes up and down”. Real water-particle motion can be more complex than this GCSE model.

1(b) The buoy completes 30 oscillations in 75 s. Calculate the frequency. **[1 mark]**

Answer / mark points: $f = 30 / 75 = 0.40 \text{ Hz}$. [1]

1(c) A test wave has frequency 0.40 Hz and wavelength 15 m. Calculate its speed. **[1 mark]**

Answer / mark points: $v = f\lambda = 0.40 \times 15 = 6.0 \text{ m s}^{-1}$. [1]



1 Checking the wave calculations continued

1(d) Another test wave travels at 5.0 m s^{-1} with frequency 0.25 Hz . Calculate its wavelength. [1 mark]

Answer / mark points: $\lambda = v / f = 5.0 / 0.25 = 20 \text{ m}$. [1]

1(e) A travelling wave on a sensor cable has speed 18 m s^{-1} and wavelength 0.60 m . Calculate its frequency. [1 mark]

Answer / mark points: $f = v / \lambda = 18 / 0.60 = 30 \text{ Hz}$. [1]

1(f) A second cable test uses frequency 24 Hz and wavelength 75 cm . Calculate the wave speed in m s^{-1} . [2 marks]

Answer / mark points: $75 \text{ cm} = 0.75 \text{ m}$. [1] $v = 24 \times 0.75 = 18 \text{ m s}^{-1}$. [1]

2 Reading the harbour snapshot

Figure 1 is the water surface at ONE instant. The wave travels horizontally. The model warning is triggered when peak-to-trough height exceeds 0.70 m .

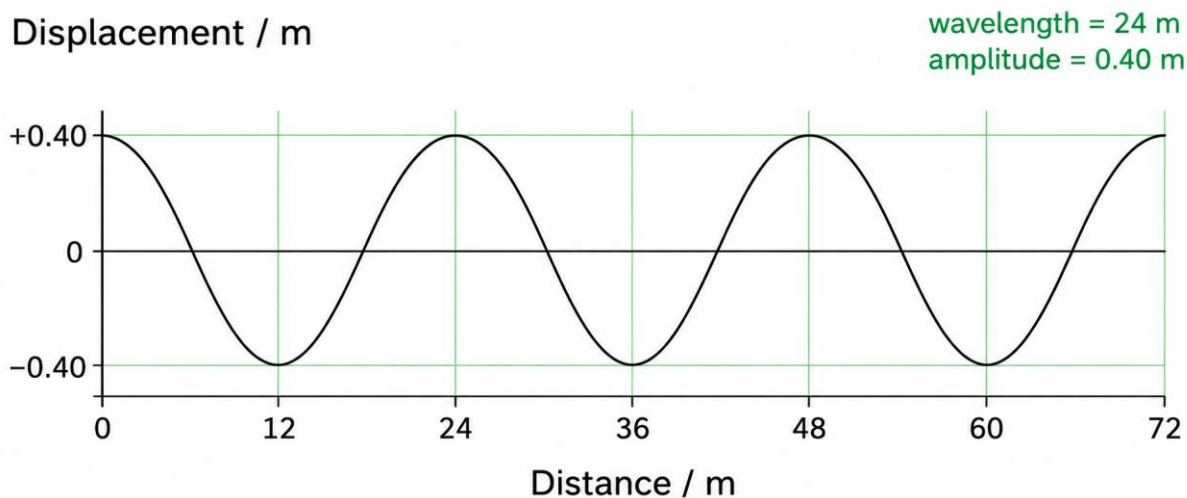


Figure 1

2(a) Read the wave's amplitude from Figure 1. [1 mark]

Answer / mark points: 0.40 m . [1] Accept 0.4 m .

2(b) Use the span from the first crest to the last crest to calculate the wavelength. Show the number of wavelength intervals. [2 marks]

Answer / mark points: There are three wavelength intervals over 72 m . [1] $\lambda = 72 / 3 = 24 \text{ m}$. [1]



2 Reading the harbour snapshot continued

2(c) Calculate the peak-to-trough height and decide whether the model warning is triggered. [2 marks]

Answer / mark points: Height = $0.40 - (-0.40) = 0.80$ m (or 2×0.40). [1] Yes: 0.80 m exceeds 0.70 m. [1]

Teacher prompt: Amplitude is not peak-to-trough height. The decision must compare the calculated height with the supplied rule.

2(d) A student counts four crests and calculates $72 / 4 = 18$ m. Explain why this wavelength is incorrect. [2 marks]

Answer / mark points: Four crests enclose only three complete wavelength intervals. [1] Divide the 72 m crest-to-crest span by three, not four. [1]

2(e) A floating marker bobs as wave crests pass, but stays near the same horizontal position. Explain what this shows about wave transfer. [2 marks]

Answer / mark points: The wave transfers energy across the water. [1] The marker/water oscillates locally rather than travelling along with each crest; there is no net transport of the medium in this model. [1]

Teacher prompt: Do not write "particles do not move": they oscillate. The evidence is no net displacement with the travelling wave.

3 Using the buoy record

Figure 2 records ONE buoy's vertical displacement as the same regular waves pass it. The buoy is moored and has no net horizontal motion.

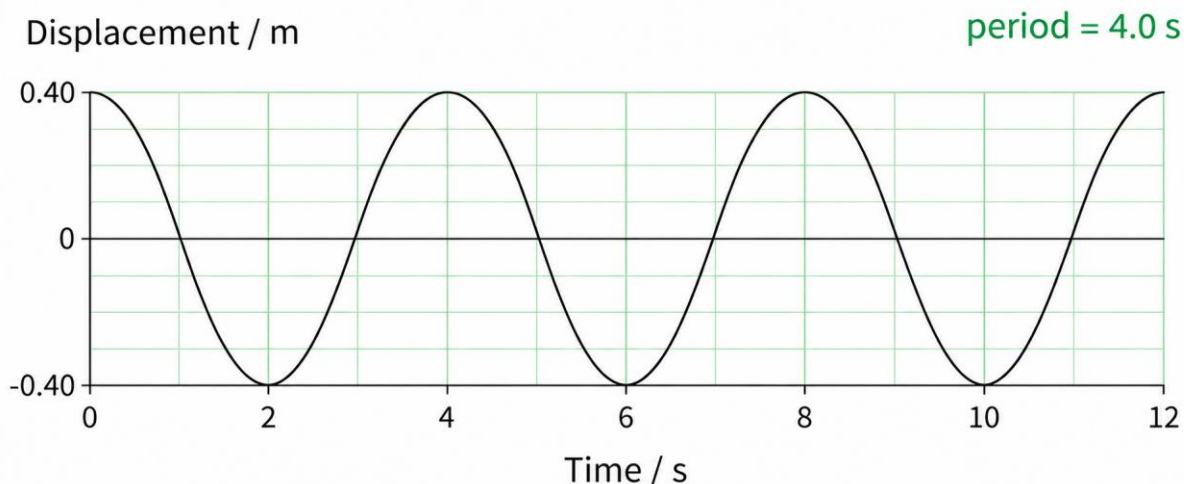


Figure 2

3(a) Read the period from Figure 2. Use two equivalent points on successive oscillations. [1 mark]

Answer / mark points: $T = 4.0$ s, for example from the crest at 0 s to the crest at 4 s. [1]

3(b) Calculate the frequency of the harbour waves. [1 mark]

Answer / mark points: $f = 1 / T = 1 / 4.0 = 0.25$ Hz. [1] Also accept three complete oscillations / 12 s.



3 Using the buoy record continued

3(c) Use Figures 1 and 2 to calculate the harbour wave speed. [1 mark]

Answer / mark points: $v = f\lambda = 0.25 \times 24 = 6.0 \text{ m s}^{-1}$. [1]

3(d) A student says the buoy moves at the speed calculated in 3(c). Explain why this is wrong. [2 marks]

Answer / mark points: 6.0 m s^{-1} is the speed of the wave/disturbance moving horizontally. [1] The buoy oscillates vertically about its equilibrium position; its instantaneous speed changes and is not this wave speed. [1]

3(e) Later, the buoy record has amplitude 0.20 m but still shows three complete oscillations in 12 s. The wavelength remains 24 m. A student says the wave speed has halved. Explain why the data do not support this. [2 marks]

Answer / mark points: Frequency is unchanged: $3 / 12 = 0.25 \text{ Hz}$. [1] Wavelength is also unchanged, so $v = f\lambda$ remains 6.0 m s^{-1} ; halving amplitude alone does not halve wave speed. [1]

3(f) An incoming wave crest is detected 180 m from the gate. Use the wave speed in 3(c) to calculate the time until that crest reaches the gate. [1 mark]

Answer / mark points: $t = \text{distance} / \text{speed} = 180 / 6.0 = 30 \text{ s}$. [1]

3(g) The warning system takes 8.0 s to process the detection. The gate then needs 25 s to close. Use 3(f) to decide whether it closes before the detected crest arrives. [2 marks]

Answer / mark points: Time left after processing = $30 - 8.0 = 22 \text{ s}$. [1] No: 22 s is less than the 25 s closing time (or total delay 33 s > 30 s; closure is 3 s too late). [1]

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4 Testing water waves in the laboratory

Figure 3 is a top view of a ripple tank. A motor-driven dipper produces straight wavefronts. The ruler is parallel to wave travel, in the plane of the water surface. A camera above the tank can record waves and a calibration ruler. The drawing is not a numerical scale.

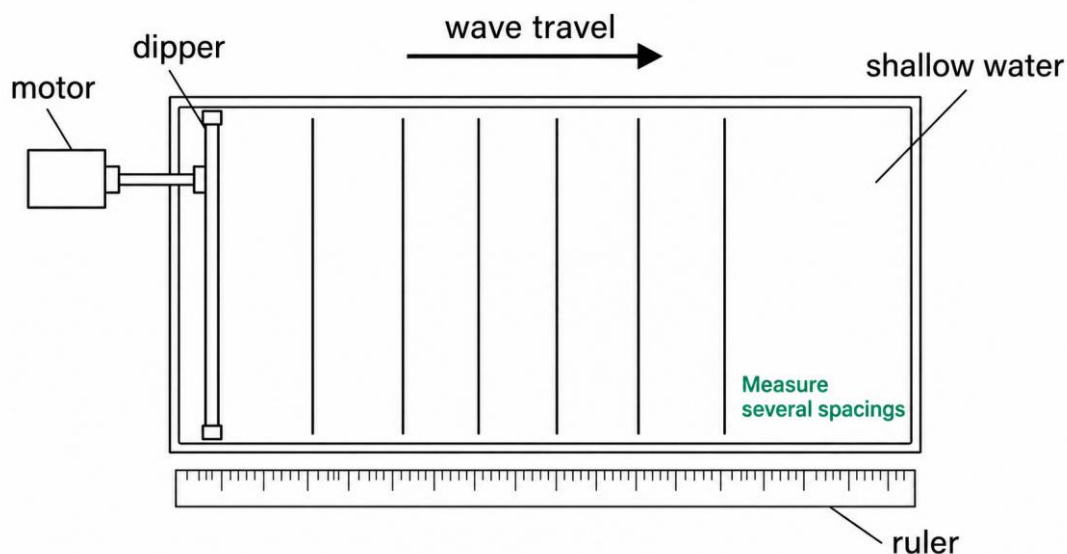


Figure 3

4(a) A calibrated video frame shows five consecutive crests. The distance from the first to the fifth is 16.0 cm. Calculate the wavelength in metres. **[2 marks]**

Answer / mark points: Five crests give four intervals: $\lambda = 16.0 / 4 = 4.0$ cm. [1] 4.0 cm = 0.040 m. [1]

4(b) The dipper completes 20 oscillations in 5.0 s of real recording time. Calculate the frequency. **[1 mark]**

Answer / mark points: $f = 20 / 5.0 = 4.0$ Hz. [1]

4(c) Use 4(a) and 4(b) to calculate the speed of the ripples. **[1 mark]**

Answer / mark points: $v = f\lambda = 4.0 \times 0.040 = 0.16$ m s⁻¹. [1]



4 Testing water waves in the laboratory continued

4(d) Explain why measuring across four wavelength intervals and timing many oscillations improves the measurements compared with measuring only one of each. **[2 marks]**

Answer / mark points: For the same ruler/end-point reading uncertainty, measuring a longer span reduces its fractional contribution to one wavelength. [1] Timing many cycles reduces the fractional effect of start/stop reaction-time uncertainty on one period/frequency measurement. [1]

Teacher prompt: “More accurate” alone is insufficient; link each longer measurement to the effect of reading or timing uncertainty. Repeats do not remove a systematic scale error.

4(e) Write a method to determine ripple speed using Figure 3 and a camera. Include how to measure wavelength and frequency, check the scale, improve reliability and work safely. Use this order: set up → distance measurement → timing → calculation → checks. **[6 marks]**

Answer / mark points: Model method: Level the tank and use shallow water. Adjust the motor-driven dipper to produce clear, low-frequency straight ripples. Place a ruler parallel to wave travel in the water-surface plane and view from directly above. Record a ruler and the waves together so the image scale is calibrated; do not assume a projected/enlarged image has the real wavelength. Freeze a clear frame. Measure from one crest to a later crest and divide by the number of crest-to-crest intervals. Convert the wavelength to metres. Use the original recording time or known frame rate to time several COMPLETE dipper oscillations, then calculate $f = \text{number} / \text{time}$. Slow-motion playback time is not real elapsed time.

Calculate $v = f\lambda$. Repeat distance and timing measurements, find means, and keep water depth and drive setting unchanged during each set. Keep electrical equipment and hands dry; use a low-voltage supply and deal with spills.

Holistic marking: 5–6 for a logically ordered usable method measuring BOTH wavelength and frequency with a valid scale and speed calculation; 3–4 for a mostly workable method with an omission; 1–2 for isolated relevant steps. 0 for no relevant physics. Choose the level, then the mark for completeness and clarity; do not award six automatic ticks.

Teacher prompt: Frequency measures oscillations per second, not the number of crests visible in one still image. Calibration, repeated measurements and safe electrical handling should be explicit.

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5 Testing waves in a solid

The sensor cable is modelled by a stretched string in Figure 4. Waves travelling along the string form a stationary pattern of loops. You do not need to explain how it forms. Each loop is HALF a wavelength. The measured span is from the first stationary point to the bridge.

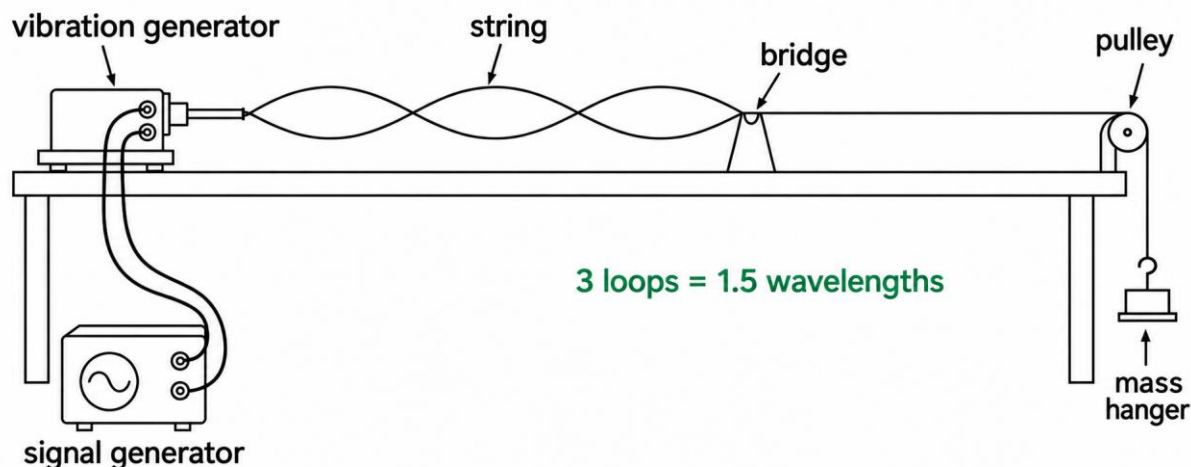


Figure 4

5(a) Moving points on the string vibrate up and down while the waves that form the pattern travel along the string. Identify the wave type and explain your choice. **[2 marks]**

Answer / mark points: Transverse. [1] String oscillation is perpendicular to the direction of the waves travelling along it. [1] The stationary pattern itself does not travel.

5(b) The span shown contains three equal loops and measures 0.90 m. Calculate the wavelength. **[2 marks]**

Answer / mark points: One loop = $0.90 / 3 = 0.30 \text{ m}$ = half a wavelength. [1] $\lambda = 2 \times 0.30 = 0.60 \text{ m}$. [1]

Teacher prompt: Do not treat one loop as a full wavelength. Equivalently, 0.90 m spans 1.5 wavelengths.

5(c) The signal generator is set to 25 Hz. Calculate the speed of the waves on the string. **[1 mark]**

Answer / mark points: $v = f\lambda = 25 \times 0.60 = 15 \text{ m s}^{-1}$. [1] This is wave speed, not speed of a loop moving along the apparatus.

5(d) Describe how this apparatus can measure frequency, wavelength and wave speed. Include how to obtain a clear pattern and improve the length measurement. **[3 marks]**

Answer / mark points: Read frequency from the signal generator. [1] Adjust the bridge position/tension to obtain clear loops; measure a span of several loops between stationary points with a ruler, divide by loop count and multiply by two for wavelength. [1] Repeat/average length readings, convert to metres and calculate $v = f\lambda$. [1] Keep the chosen frequency/tension unchanged during each set of length readings.

Teacher prompt: The stationary pattern is a measurement aid; v is not zero. Several loops reduce the fractional ruler-reading uncertainty. Secure the pulley and put a tray below the hanger.



6 Checking the air horn

The harbour air horn sends a sound pulse through air. Two microphones on its path are connected to an electronic timer/data logger.

6(a) Sound is longitudinal. Describe how air particles move relative to wave travel and describe the particle spacing in compressions and rarefactions. **[2 marks]**

Answer / mark points: Particles oscillate back and forth parallel to wave travel. [1] They are closer together in compressions and farther apart in rarefactions. [1]

6(b) The microphones are 1.02 m apart. The same pulse reaches the second 0.0030 s after the first. Calculate the speed of sound. **[1 mark]**

Answer / mark points: $v = \text{distance} / \text{time} = 1.02 / 0.0030 = 340 \text{ m s}^{-1}$. [1]

6(c) Describe a method using the two microphones to measure sound speed. Include the measured distance and time, a calculation and one improvement. **[3 marks]**

Answer / mark points: Place both microphones on the same straight sound path, with the pulse source beyond the first microphone; measure separation d with a ruler/tape. [1] Use a logger/electronic timer to find the arrival-time difference Δt for the SAME pulse and calculate $v = d / \Delta t$. [1] Repeat and average / use a larger separation for a larger delay / work away from reflecting surfaces and identify the first arrivals. [1]

Teacher prompt: Do not use the source-to-second-microphone distance with the difference between the two microphone arrival times. Ordinary stopwatch reaction time is too large for this millisecond delay.

7 Separate Physics only Sound in a different medium

A 500 Hz source sends sound from air into water. Sound speed is 340 m s^{-1} in air and 1500 m s^{-1} in water. The source frequency is unchanged.

7(a) Calculate the wavelength of this sound in air. **[1 mark]**

Answer / mark points: $\lambda = v / f = 340 / 500 = 0.68 \text{ m}$. [1]

7(b) Calculate the wavelength in water and explain why it differs from the value in air. **[3 marks]**

Answer / mark points: $\lambda = 1500 / 500 = 3.0 \text{ m}$. [1] Frequency remains set by the source at 500 Hz. [1] Sound speed is greater in water, so at unchanged frequency its wavelength is greater ($v = f\lambda$). [1]

Teacher prompt: This sound-medium relationship is Separate Physics content, accessible to both tiers. Do not add an automatic Higher-only tag or claim frequency increases at the boundary.

Review and improve

Count intervals, not crests. Amplitude is measured from the undisturbed position. Wave speed describes the travelling disturbance, not the speed of an oscillating particle.

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