AQA AS Progressive Waves, Phase and Polarisation solutions

Matching solutions and teaching prompts for the class review

Specification points covered

• 3.3.1.1(a) Amplitude, frequency, wavelength, speed and phase. • 3.3.1.1(b) Use c = fλ. • 3.3.1.1(c) Use f = 1/T. • 3.3.1.1(d) Phase in radians, degrees or fractions of a cycle. • 3.3.1.2(a) Longitudinal and transverse waves. • 3.3.1.2(b) Sound, electromagnetic and string-wave examples.	• 3.3.1.2(c) Displacement or field oscillation and energy propagation. • 3.3.1.2(d) Common electromagnetic-wave speed in vacuum. • 3.3.1.2(e) Polarisation as evidence for transverse waves. • 3.3.1.2(f) Polaroid filters and aerial alignment. • 3.3.1.2(g) Malus' law is not required.

Teaching focus

Insist on precise particle, wave and energy language as well as correct calculations.
Use each common-error prompt to correct the pupil's model or reasoning, not only the final answer.

1. The acoustic pulse

1. A whale tag emits an acoustic pulse through seawater. Explain why the sound is longitudinal and distinguish the direction of particle displacement from the direction of energy transfer. [4 marks]

Answer / mark points: The water particles oscillate parallel to the direction in which the sound travels, so it is longitudinal. Compressions and rarefactions move through the water. Energy is transferred along the wave; particles oscillate about equilibrium rather than moving with the pulse.

Teacher prompt / common error: Do not describe the particles moving from the whale to the receiver. Separate local displacement from energy propagation.

2. The tag emits at 30.0 kHz. The speed of sound in seawater is 1500 m s^{-1}. Calculate the period and wavelength of the wave. [3 marks]

Answer / mark points: $T = 1/f = 1/(30.0 \times 10^3) = 3.33 \times 10^{-5}$ s. $\lambda = v/f = 1500/(30.0 \times 10^3) = 5.00 \times 10^{-2}$ m.

Teacher prompt / common error: Convert kilohertz before calculating period and wavelength.

2. Phase along the wave

3. Two hydrophones lie on the direction of travel and are 12.5 mm apart. Calculate their phase difference in degrees and radians for the wave in Question 2. [3 marks]

Answer / mark points: The separation is 12.5/50.0 = 0.250 wavelength. Phase difference = 0.250 × 360° = 90.0° = π/2 rad.

Teacher prompt / common error: Phase is a fraction of a cycle; give both requested angular units.

4. At one instant, hydrophone A is at maximum positive displacement. State the displacement and phase of a point half a wavelength farther along the same wave. [2 marks]

Answer / mark points: Half a wavelength is a phase difference of 180° or π rad. The point is at maximum negative displacement.

Teacher prompt / common error: Half a wavelength means antiphase, not zero phase difference.

5. A pulse takes 7.50 s to travel from the tagged whale to a hydrophone. Calculate the distance to the whale. Explain why the water particles do not travel this distance with the pulse. [3 marks]

Answer / mark points: Distance = vt = 1500 × 7.50 = 1.125×10^4 m = 11.25 km. Water particles oscillate locally about equilibrium while energy and the disturbance propagate.

Teacher prompt / common error: The wave travels the distance; individual water particles do not.

3. Radio link

6. The surface buoy sends data to a satellite at 800 MHz. Calculate the wavelength in vacuum and state what happens to all electromagnetic-wave speeds in vacuum when frequency changes. [3 marks]

Answer / mark points: $\lambda = c/f = (3.00 \times 10^8)/(800 \times 10^6) = 0.375$ m. All electromagnetic waves travel at the same speed c in vacuum; changing frequency changes wavelength instead.

Teacher prompt / common error: Frequency does not change the vacuum speed of an electromagnetic wave.

7. Two radio paths to the receiver differ in length by 0.125 m. Calculate the phase difference caused by this path difference for the wavelength in Question 6. [3 marks]

Answer / mark points: Fraction of a cycle = 0.125/0.375 = 1/3. Phase difference = 120° = 2π/3 rad.

Teacher prompt / common error: Use path difference divided by wavelength before converting to an angle.

8. The received radio signal has a larger amplitude after the transmitter power is increased. State what amplitude describes for a progressive wave and explain what is being transported to the satellite. [2 marks]

Answer / mark points: Amplitude is the maximum displacement from equilibrium, or maximum field strength for an electromagnetic wave. A larger amplitude corresponds to a greater rate of energy transfer; energy is transported, not matter.

Teacher prompt / common error: For electromagnetic waves, amplitude refers to field oscillations rather than material-particle displacement.

4. Polarisation in practice

9. The satellite signal can be received through one orientation of a polarising filter but not through the perpendicular orientation. Explain how this observation supports the statement that electromagnetic waves are transverse. **[3 marks]**

Answer / mark points: A polarising filter selects oscillations in one transverse direction. Extinction after a 90° rotation shows that the field oscillation has a direction perpendicular to propagation, which a longitudinal wave could not satisfy.
Teacher prompt / common error: Polarisation is evidence for transverse waves because only transverse oscillations have a selectable direction perpendicular to propagation.

10. A storm twists the buoy's transmitting aerial through 90° while the satellite aerial remains fixed. Predict and explain the effect on the received signal, and state one corrective action. **[3 marks]**

Answer / mark points: With the aerials perpendicular, the received signal is greatly reduced or can fall to a minimum because the transmitted polarisation is misaligned with the receiving aerial. Rotate or stabilise one aerial so the aerials are parallel.
Teacher prompt / common error: Use aerial alignment language; no Malus-law calculation is required.

11. Reflected glare entering an onboard camera is unpolarised before reflection and strongly plane-polarised afterwards. Describe unpolarised light and explain how rotating a Polaroid filter can reduce the glare. **[3 marks]**

Answer / mark points: Unpolarised light has transverse oscillations in many random directions perpendicular to propagation. A Polaroid transmits the component along its transmission axis; rotating it until that axis is perpendicular to the glare's polarisation reduces the transmitted glare.
Teacher prompt / common error: Unpolarised does not mean no oscillation. It means many transverse orientations.

5. Connecting the system

12. The whale changes its call from 15 kHz to 30 kHz in the same water. Compare the wavelength, period and wave speed of the two calls. [3 marks]

Answer / mark points: Doubling frequency from 15 kHz to 30 kHz halves the period and, because speed in the same water is unchanged, halves the wavelength. The wave speed remains 1500 m s^{-1}.

Teacher prompt / common error: In one medium, speed is fixed by the medium, so f and λ change inversely.

13. Recommend how the team should use the hydrophones and buoy aerial to identify the whale call and maintain a reliable satellite link. Use frequency, wavelength, phase, wave type and polarisation precisely. [5 marks]

Answer / mark points: A high-level response should identify sound as longitudinal and radio as transverse; use $f = 1/T$ and $v = f\lambda$ to match the acoustic signal; compare phase at separated hydrophones to infer path or direction; recognise that hydrophone spacing gives a calculable fraction of a cycle; align transmitting and receiving aerials because radio is plane-polarised; and monitor frequency or phase without claiming that water or charge travels from whale to satellite. Award any five linked points.

Teacher prompt / common error: Use the correct verb: a quantity increases, decreases or stays the same; a particle oscillates; energy propagates.

Language and method check

Award independent, creditworthy physics steps; do not award extra marks for repeated statements.
Accept equivalent methods when the physical reasoning, units and final precision remain consistent.