Mark scheme for Extension Worksheet – Topic 4, Worksheet 4

1 **a** A longitudinal standing wave is set up in the tube; the sand is pushed away from antinodes because air molecules move; and so collect at points where air molecules do not move, i.e. at nodes. [3]

b The wavelength is double the node-to-node distance i.e. 4.8 cm or 0.048 m; so the speed of sound is $v = \lambda f = 0.048 \times 6700 = 322\ \text{m s}^{-1}$ [2]

2 **a** The loud sound is heard when there is a standing wave in the tube; this only happens for specific air column lengths. [2]

b The wavelength is $\lambda = 2 \times 0.22 = 0.44\ \text{m}$; and so $v = \lambda f = 0.44 \times 720 = 317\ \text{m s}^{-1}$ [2]

3 The wavelength is $\lambda = \frac{v}{f} = \frac{180}{45} = 4.0\ \text{m}$; since $\lambda = 2L \Rightarrow L = 2.0\ \text{m}$ [2]

4 The statement is false; at a time when the standing wave is the red wave the point is the centre of a compression but at the time when the wave is the blue wave it is the centre of a rarefaction; the point at 1.5 m oscillates so it is sometimes at the centre of a compression and sometimes at the centre of a rarefaction. [3]

5 **a** Each particle executes simple harmonic oscillations and so the acceleration is opposite to displacement, i.e. vertically down. [1]

b The speed of the particle is $v = \omega\sqrt{y_0^2 - y^2}$.; since $\omega = 2\pi f = 2.26 \times 10^2\ \text{s}^{-1}$; we have that $v = 2.26 \times 10^2 \sqrt{0.040^2 - 0.020^2} = 7.8\ \text{m s}^{-1}$ [3]

c The wavelength of the wave is 4.0 m; and so the speed is $c = 36 \times 4.0 = 144\ \text{m s}^{-1}$ [2]

d A standing wave is formed when two travelling waves moving in opposite directions superpose; the speed of a standing wave refers to the speed of the its constituent travelling waves. [2]

6 **a** If the 'moving' observer considers herself to be at rest then the air carrying the wave moves at speed v with respect to the observer; and so the speed of the sound wave itself is $c + v$ with respect to her. [2]

b The observer measures a frequency given by $f' = \frac{c+v}{c} f$; and so a wavelength

$$\lambda' = \frac{c+v}{f'} = \frac{c+v}{\frac{c+v}{c} f} = \frac{c}{f} = \lambda$$ [2]

c The wavefronts emitted by the source are circular and have a common centre; so the moving observer measures the same distance between the wavefronts as the source i.e. the same wavelength. [2]

7 **a** The maximum speed is $v_{\max} = \omega x_0$. Since $\omega = 2\pi f = 2\pi \times 25 = 1.57 \times 10^2 \text{ s}^{-1}$; we have that $v_{mx} = 1.57 \times 10^2 \times 0.050 = 7.85 \text{ m s}^{-1}$ [2]

b The extremes in frequency will take place when the plate is moving past its equilibrium position; if plate is moving to the left (away from the wave) then the received frequency at the plate is

$f' = \frac{c-v}{c} f = \frac{340-7.85}{340} \times 1200 = 1172 \text{ Hz}$; this is now reflected so the frequency received is $f'' = \frac{c}{c+v} f = \frac{340}{340+7.85} \times 1172 = 1146 \text{ Hz}$; if the plate is moving to the right then the received frequency at the plate is

$f' = \frac{c+v}{c} f = \frac{340+7.85}{340} \times 1200 = 1228 \text{ Hz}$; this is now reflected so the frequency received is $f'' = \frac{c}{c-v} f = \frac{340}{340-7.85} \times 1228 = 1257 \text{ Hz}$; the range is then to 3 significant figures, $[1146, 1257] \text{ Hz} \approx [1150, 1260] \text{ Hz}$ [6]