Assessment Schedule – 2021

Physics: Demonstrate understanding of wave systems (91523)

Evidence

Q	Evidence	Achievement	Merit	Excellence
ONE (a)	$n\lambda = \frac{dx}{L}$ At the first minimum: $0.5(0.381) = \frac{1.50x}{L}$ $x = 3.175 = 3.18$ m (3sf)	• Correct answer *Alternative approach using $d\sin\theta$ is more accurate.* $x = 3.2009$ m		
(b)	At A, there is no path difference between the waves from both speakers and so the waves arrive in phase. This causes the waves to constructive interfere producing a loud sound. As the phone is moved towards B, the **path difference** of the sound from the two speakers **increases**. This introduces an **increasing phase difference,** and the resulting superposition produces a sound with a gradually decreasing volume. At the quiet point, the path difference is half a wavelength, so the sound waves from the two speakers are 180 degrees out of phase– and so **destructive interference** occurs, and the sound is quiet. Moving further towards B, the path and **phase difference increases** further, such that there is **incomplete cancellation,** and the sound becomes increasingly louder. (Beyond B the path difference of a whole wavelength occurs, so waves arrive in phase and there is a loud point.)	• Explains changing volume in terms of path difference OR phase difference OR consequent superposition.	• Explains changing volume in terms of: path difference, OR phase difference, AND consequent superposition.	
(c)	Increasing the distance between the speakers will result in the antinodal and nodal lines being closer together. Since $n\lambda = d\sin\theta$, when d increases, θ will decrease; hence $\sin\theta$ will also decrease, causing the loud and soft sounds to occur closer to each other. Alternatively $n\lambda = \frac{dx}{L}$ if d increases, x decreases, when n, λ, L constant.	• Says the loud and soft sounds will be **closer** to each other.	• Explains the reason why the loud and soft sounds will be closer to each other when the distance between the speakers increases.	

(d)(i) (ii)	The beat frequency = 895 – 890 = 5 Hz. They hear beats because the waves from the two sources have slightly different frequencies, so they are regularly moving between being **in phase** (making **loud sounds** due to **constructive interference**) and **out of phase** (making **quieter sounds due** to **destructive interference**). The initial beat frequency will be 5 Hz. But as the teacher increases the frequency of Speaker 2, the **beat frequency will decrease** until **no beats are heard, when the frequencies are the same.** Further increasing the frequency to 900 Hz will result in beats being formed again, and **becoming more frequent**, reaching 5 Hz when f_2 = 900 Hz.	• ONE of: Calculate initial beat frequency. OR Explain why they hear beats. OR Describe the changes to the beat frequency as frequency of Speaker 2 is increased.	• TWO of: Calculate initial beat frequency. OR Explain why they hear beats. OR Describe the changes to the beat frequency as frequency of Speaker 2 is increased.	• Complete answer: Calculate initial beat frequency. AND Explain why they hear beats. AND Describe the changes to the beat frequency as frequency of Speaker 2 is increased.

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a or 1a + 1m	2a + 1m or 2m	1a + 2m or 2a + 1e	2a + 2m or 1a + 1m + 1e	2m + 1e or 2a + 1m + 1e	1a + 2m + 1e

Q	Evidence	Achievement	Merit	Excellence
TWO (a)	$\lambda = 4L = 4 \times 1.20 = 4.80$ m	• Correct answer.		
(b)	N A N A N A N A N A These have frequencies of $3f_0$ and $5f_0$. **Nodes and antinodes are equally spaced**	• One diagram correct. OR One correct harmonic noted.	• Complete correct answer. Note: $f_0 = 71.14$ $3f_0 = 213.125$ $5f_0 = 355$	
(c)	Marc's lips produce many frequencies. The sound waves travel down the tube and **reflect** off the closed end (with a π phase change, destructively interfering with itself) and the open end (with no phase change, constructively in interfering with itself). If the wavelength is such that it fits the pipe (odd multiples of ¼ wavelengths) so that the open end is always an antinode and the closed end a node, the multiple reflections will produce a standing wave with nodes (destructive interference) and antinodes (constructive interference) in fixed positions, as the energy of the wave builds, the amplitude increases causing the pipe to resonate. Those frequencies (/wavelengths) that do not meet the end conditions, are not able to build in energy and so no sound is heard.	• Only the resonant frequencies having wavelengths **fitting** the pipe by. Mentions ONE of: Reflections at the ends. OR Interference pattern. OR End conditions / odd mulitples of $\frac{1}{4}\lambda$.	• Any valid reason leading to the resonant frequencies having wavelengths fitting. Mentions TWO of: Reflections at the ends. OR Interference pattern. OR • End conditions / odd mulitples of $\frac{1}{4}\lambda$.	• Complete answer that refers to the resonant frequencies having wavelengths **fitting** by: Full answer: **Reflection** at the end with incident and reflected waves **interfering** to produce standing wave with (**end conditions)** A at the open end and N at the closed.
(d)	$v = f\lambda$ λ of all the harmonics are determined by the length of the pipe, so are unchanged (constant). As v increases, f must increase for all the resonant frequencies.	• Frequency increases.	• Complete answer. λ constant (as L is constant) v increases f increases.	

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a or 1a + 1m	2a + 1m or 2m	1a + 2m or 2a + 1e	2a + 2m or 1a + 1m + 1e	2m + 1e or 2a + 1m + 1e	1a + 2m + 1e

Q	Evidence	Achievement	Merit	Excellence
THREE (a)	$f' = f\left(\dfrac{v_w}{v_w - v_s}\right)$ $650 = f\left(\dfrac{341}{341 - 44.4}\right)$ $f = 565\ \text{Hz}$	• Correct show.		
(b)	As the car moves along, the wavefronts of the sound waves from the engine move out in all directions, spherically. Each spherical wavefront has its centre a little closer to Susan, than it would if it was stationary, causing the wavefronts to appear bunched. Thus, the waves approaching Susan have a smaller wavelength than normal. Since their speed is unchanged and $v = f\lambda$, the smaller wavelength is heard as a higher frequency (a different note). Meanwhile, in the car, the driver remains in the centre of the wave fronts / with no relative motion between him and the engine, there is no Doppler shift and the driver hears the actual frequency of the engine.	• ONE of λ decreases f increases $v_{rel} = 0$ driver actual f (not waves bunched)	• Explains Doppler λ decreases f increases OR Explains lack of Doppler shift for driver. $v_{rel} = 0$ driver actual f	• Explains Doppler. AND Explains lack of Doppler shift for driver.
(c)	$f' = f\left(\dfrac{v_w}{v_w - v_s}\right)$ $500 = 564\left(\dfrac{341}{341 + v_s}\right)341 =$ $v_s = 44.3\ \text{m s}^{-1}$ $v_s = 44.6\ \text{m s}^{-1}$ if unrounded values used. OR $f' = 565\left(\dfrac{341}{341 + 44.4}\right)$ $= 499.9\ \text{Hz}$	• Attempts to solve for v_s with correct equation and substitution. OR Guess and check f'.	• Correct answer for v_s. OR no change in f' • so v_s unchanged.	

(d)	Calculations are not needed but can be done: New frequency is 10% more than 565 Hz, i.e. 621.5 Hz New speed is 10% more than 44.4 m s^{-1}, i.e. 48.84 m s^{-1} $f' = f\left(\frac{v_w}{v_w + v_s}\right) = 621.5\left(\frac{341}{341 + 48.84}\right) = 544$ Hz Susan will hear the frequency increases. Accept logical answer based on formula. (The 10% increase in engine frequency is much greater than the decrease in frequency due to Doppler.)	• Correct source frequency AND v_s calculation. OR Good estimate with flakey logic for final answer.	• Correct **apparent** frequency calculation. OR Logical answer based on formula. (Note that candidates could just consider $\frac{v_w}{v_w + v_s}$ and how this is shifting by less than 10%.)	

NØ	N1	N2	A3	A4	M5	M6	E7	E8
No response; no relevant evidence.	1a	2a	3a or 1a + 1m	2a + 1m or 2m	1a + 2m or 2a + 1e	2a + 2m or 1a + 1m + 1e	2m + 1e or 2a + 1m + 1e	1a + 2m + 1e

Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 6	7 – 13	14 – 19	20 – 24