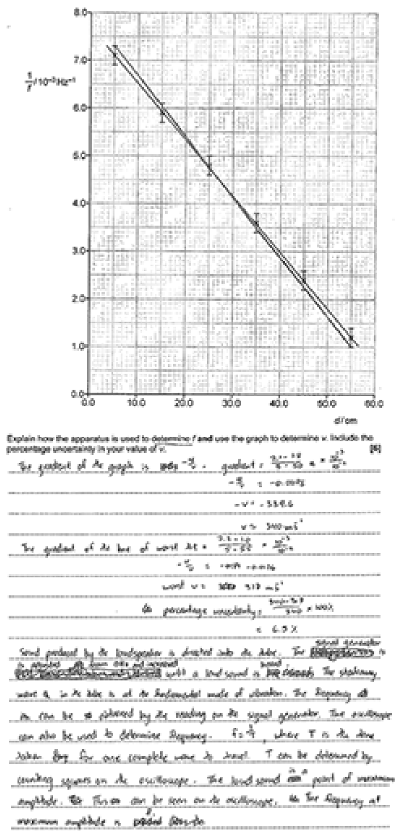
Mark scheme

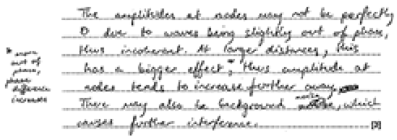
Question			Answer/Indicative content	Marks	Guidance
1	a		$\lambda = \frac{v}{f}$ $(= \frac{340}{262})$ $\lambda = 2L$ $(L =) \frac{1.30}{2} = 0.65$ (m)	B1 B1 B1	Formula may be implied by substitution **Allow** *c* for *v* Relationship may be inferred from a correct diagram of fundamental drawn in a tube open at both ends,or from a statement such as 'half a wavelength fits inside the tube' Some working leading to correct answer must be shown; don't accept a bald answer **Allow** *L* = 0.649 (0.64885) as evidence of working Do not allow working backwards from the answer **Examiner's Comments** This is a 'show that' question and so every step of the calculation needs to be made clear. It is not enough to point out that 340 / (2 × 262) = 0.65: the examiner needs to know why the data is being combined in this particular way. The step that was most often omitted was saying that, for the fundamental (lowest) frequency, half a wavelength fits inside the flute. This could be demonstrated using a diagram, showing an open tube containing half a wavelength with antinodes at both ends. However, a written statement (length is half of a wavelength) or a mathematical statement ($L = \lambda/2$) are just as good.
	b	i	Any **two** from • particles occupy negligible volume (compared to volume of container/gas) • collisions are (perfectly) elastic • time of collisions is negligible (compared to the time between collisions) • negligible forces exist between particles (except during collisions)	B1 × 2	Mark as for Short Answer Questions (requiring only a list by way of a response) and contradictory responses see page 3. **Allow** zero / no / none for negligible throughout **Ignore** particles occupy negligible space **Ignore** particles are very small **Allow** kinetic energy is conserved (during collisions) **Allow** the particles move at constant velocity (in between collisions) **Ignore** type of force if specified **Examiner's Comments** Most candidates confidently wrote two correct assumptions. Errors most often came about through careless wording, such as 'the time between collisions is negligible' (rather than the time of collisions) or 'the particles take up negligible space' (rather than volume).

		ii	$M = 4.00 \times 10^{-3}$ (kg mol^{-1}) $T = 263$ (K) $v^2 = \frac{1.67 \times 8.31 \times 263}{4.00 \times 10^{-3}}$ $v = 955$ (m s^{-1}) $f = (\frac{v}{\lambda} =) \frac{955}{1.30}$ = 730 (Hz) **Alternative method using ratios** $\frac{f_1}{f_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2}$ or $\frac{v_1}{v_2} = \left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2}$ $T = 263$ (K) $\left(\frac{\gamma_1 T_1 M_2}{\gamma_2 T_2 M_1}\right)^{1/2} = \left(\frac{1.67 \times 263 \times 29}{1.4 \times 293 \times 4}\right)^{1/2}$ = 2.786 f (= 2.786 × 262) = 730 (Hz)	C1 C1 C1 A1 C1 C1 C1 A1	This C1 mark is for converting *M* into kg mol^{-1} **Allow ECF** for an incorrect POT in *M* *T* = -10 (K) is **XP** onwards (first C1 mark can still be scored) but **allow ECF** for incorrect conversion of *T*. This C1 mark is for correct substitution into the given formula; v^2 does not need to be calculated for the mark but seeing *v* = 955 implies the mark **Allow** *M* given to 1sf **Allow** 8.3 or *R* for 8.31 If a value for γ or *M* is taken from the wrong row of the table, this is a TE (*M* must be in kg/mol). If both wrong values are used, count this as a single TE. **ECF** candidate's value of λ or (λ = 2L) from 1a **Allow** *f* = 740 (Hz) For reference, POT error in *M* gives *v* = 30.2 (ms^{-1}) and *f* = 23 (Hz) *T* = −10 (K) is **XP** onwards (first C1 mark can still be scored) but **allow ECF** for incorrect conversion of *T* This C1 mark is for substitution and the ratio 2.786 does not need to be calculated for the mark The values for *M* may be given in kg/mol or left in g/mol as long as there is consistency **Allow** *M* = 4 to 1sf **Allow** *f* = 740 (Hz) If using $\frac{v_1}{v_2}$ then v = 2.786 × 340 = 947 giving *f* (= *v* /*λ* = 947 / 1.3) = 730 (Hz) but **ECF** candidate's own value of *λ* or *L* (*λ* = 2L) from 1a **<u>Examiner's Comments</u>** **Common problems in 1 (b) (ii)** • failing to convert the molar mass *M* into units of kg mol^{-1} • substituting the length of the flute (0.65m) instead of 1.30m for the wavelength.
			Total	**9**	
2			**A**	1	**<u>Examiner's Comments</u>** Candidates performed well on this question with many candidates correctly determining the wavelength of the

					standing wave as 1.4 m to then use this value to calculate the frequency of the wave as 243 Hz. This demonstrated understanding that the distance between adjacent nodes is λ/2 and not λ which was indicative of the most common distractor given by the answer B.
			Total	**1**	
3			**D**	1	**Examiner's Comments** Many candidates correctly determined the correct phase difference as p between points **X** and **Y** as they interpretated that the fraction of the wave between points **X** and **Y** was the equivalent to λ/2. The most common distractor was C.
			Total	**1**	
4			A	1	**Examiner's Comments** Relatively few candidates got this phase difference correct; it was clear from many that they thought that it was a progressive wave as they attempted to add on fractions of cycles. It may also be the case that candidates are unfamiliar with phase differences in stationary waves.
			Total	**1**	
5	a		4 (ms) OR 0.004 (s) 250 (Hz)	C1 A1	**Allow** one mark for 0.25 (Hz) to any power of ten **Examiner's Comments** The majority of the candidates gained credit. Some lower scoring candidates did not interpret the trace correctly.
	b		One node drawn at closed end and one antinode drawn at open end N and A correctly labelled	B1 B1	**Examiner's Comments** Many candidates understood what was meant by an antinode and a node but did not understand that for the fundamental mode of vibration a node was formed at the closed end and one antinode was formed at the open end.
	c		(3×250=) 750 (Hz)	B1	**Allow ECF** from (a) **Not** ECF from (b) **Examiner's Comments** This question was challenging. A value of 500 Hz was the common incorrect answer. Other incorrect answers included candidates who thought that the frequencies decreased. **Misconception**

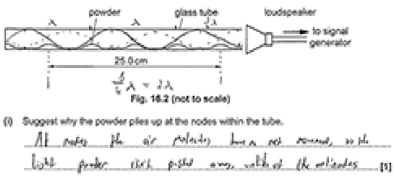
					Many candidates did not fully understand the formation of stationary waves in closed tubes and the effect on the harmonics. Candidates should have the opportunity of drawing stationary waves in both open and closed tubes and determining the wavelength and frequency for each pattern.
			Total	**5**	
6			**Level 3 (5–6 marks)** Clear description of method to determine *f* **and** graph analysed to determine *v* and the percentage uncertainty in *v* *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some description of method to determine *f* **and** some analysis of data to determine *v* or the percentage uncertainty in *v* **or** Limited description of method to determine *f* **and** graph analysed to determine *v* and an attempt to determine the percentage uncertainty in *v* **or** Clear description of method to determine *f* **and** limited analysis of graph *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description of the	B1 × 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description of method** • Adjust frequency until maximum amplitude observed / heard • Start from a low frequency • Since fundamental frequency is the lowest resonance • Measure period of wave on oscilloscope • Period = timebase x horizontal distance • *f* = 1/*T* • read frequency from signal generator. **Analysis of data** • Gradient = $-\frac{4}{v}$ • Determines gradient of line (-0.012 Hz^{-1} m^{-1}) • Determines *v* (330 to 344 m s^{-1}) • Correct power of ten and unit • Draws worst acceptable line • Determines gradient of worst acceptable line • Calculates absolute uncertainty in gradient • Determines percentage uncertainty in gradient • Percentage uncertainty in gradient = percentage uncertainty in *v* **<u>Examiner's Comments</u>** The second level of response question gave candidates the opportunity of drawing conclusions from an experiment as well as explaining how the fundamental frequency *f* may be determined experimentally. For good answers to these type of questions, candidates need to structure their answers logically so that all parts of the question are answered. An explanation to determine *f* should include the

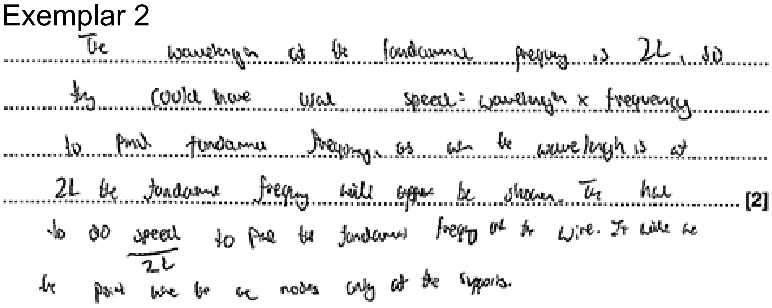
			method to determine *f* **or** Limited analysis to determine *v* *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 mark** *No response or no response worthy of credit.*		adjustment of the frequency and how to determine the fundamental frequency with the idea of the loudest sound. More successful candidates discussed the peak on the oscilloscope and starting from a low frequency. It was also expected that candidates could describe how to determine the frequency from an oscilloscope. Ideally reference would be made to the time-base. To determine the value of *v* with the percentage uncertainty, candidates needed to show their working clearly, taking into account the powers of ten and units from the graph. Exemplar 3  This candidate's response is structured and detailed. Firstly, this candidate has added the steepest worst acceptable line to the graph which passes through all the error bars. The candidate then identifies how the gradient is related to the frequency of the wave before calculating the gradient. The calculation of the gradient is demonstrated and the candidate has also clearly taken into account the powers of ten on each axis of the graph before determining *v* with a correct unit. This process is repeated for the worst acceptable line with each of the steps shown before percentage uncertainty is calculated. Throughout this

					section, it is easy to follow the candidate's method. It is clear that the candidate has used a large triangle to calculate the gradient. The candidate then explains how *f* is determined by adjusting the signal generator until a loud sound is heard and then explaining how the frequency is determined by the oscilloscope.
			Total	**6**	
7		i	Incident and reflected waves interfere / superpose AW Constructive interference /waves in phase gives maximum amplitude / anti-nodes Destructive interference/waves in antiphase gives minimum/zero amplitude / nodes	B1 B1 B1	**IGNORE** super impose **<u>Examiner's Comments</u>** About a third of candidates achieved no marks on this question but most candidates were able to correctly explain that a stationary wave is formed from the superposition of the incident and reflected wave. Often descriptions of nodes and antinodes was confused and lacked effective and correct use of scientific language by referring to constructive and destructive interference and explaining how these formed antinodes and nodes respectively.
		ii	intensity/amplitude/energy of wave decreases with distance / ORA AW reflected wave has a lower amplitude than incident wave ORA **OR** incomplete destructive interference occurs AW Difference in amplitudes increases with increasing distance from A ORA	B1 B1 B1	**ALLOW** energy absorbed when wave incident on the plate **<u>Examiner's Comments</u>** Candidates performed less well on this question with only about a third of candidates achieving 1 or more marks. Candidates had to explain both observations regarding the amplitudes of the nodes to fully access the question by interpreting that the change in amplitude was related to the decrease in intensity/amplitude of the reflected wave as it travelled a greater distance from the reflecting sheet **A**. Exemplar 1  This response is an example of a typical response where candidates have confused the change in amplitude of the nodes to either a change in frequency or phase difference due to the reflected wave being 'out of phase' with the incident wave. There was also a common misconception that the reflected wave from the reflecting sheet **A** had experienced interference from either background noise or from further reflections of the wave in the room. The

					candidates had assumed that the two waves were no longer coherent, and this resulted in a difference in the amplitude of the nodes further from the reflecting sheet **A**.
		iii	λ= 2 × 0.84 = 1.68m 336 (m s^{-1})	M1 A1	**Examiner's Comments** Candidates performed well in this question as two thirds correctly determined that the wavelength of the sound wave was twice the distance between the adjacent nodes and then applied the wave speed equation $v = f\lambda$ to calculate the speed of sound waves as 336 m s^{-1}.
		iv	**Any one from:** Measure across more than one minima Use lower frequencies Repeat and calculate means	B1	**ALLOW** use longer wavelengths **Examiner's Comments** Less than half of candidates were able to suggest a suitable improvement to the student's method to reduce uncertainty in their calculated value of the speed of sound waves in air as suggestions were often referenced to carrying out repeats but omitted that an average needed to be calculated from repeat readings to improve accuracy. Most candidates did not understand that simply increasing measurements across more nodes would have reduced the uncertainty or that by decreasing the frequency the wavelength increased and hence the uncertainty was reduced.
			Total	**9**	
8	a			B1	Both parts needed – either dotted or solid. Correct curvature needed by eye. Middle node by eye. **IGNORE** lines outside of tube **Examiner's Comments** The majority of candidates were able to correctly identify and draw the fundamental mode in between the two given lines. Examiners were fairly generous on this; however the following would be penalised: not drawing the node in the centre, having the wrong curvature, and drawing straight lines. This is a relatively simple sketch, but candidates must take care. Some candidates attempted a longitudinal wave sketch and several others just drew a large number of waves, indicating they had not really appreciated the question. As always, it is recommended that candidates use pencil; those who made mistakes often drew another set of a parallel lines and then put in their answer. Examiners will always consider this; however it is better to use the original question image.

	b		Frequency f_0 = 340 / 0.600 = **567** (Hz)	A1	Correct to at least 2 significant figures No ecf from 18(a) **<u>Examiner's Comments</u>** Around two thirds of candidates were able to calculate this correctly. The majority of incorrect responses were naturally when using 0.30 m as the wavelength. Relatively few candidates did not change their wavelength into metres, but a significant number were unable to rearrange the formula correctly.
	c		Next wavelength for standing wave is λ = 0.300m Frequency = 340 / 0.300 = **1.13 x 10^3** (Hz)	C1 A1	Ecf from (b) if wavelength used is 0.600m Correct to at least 2 significant figures **Special case:** If wavelength drawn in (a) is 0.300m and f_0 in (b) = 1130 Hz, then allow ecf (C1) for next λ = 0.200m and (A1) frequency as 1700 Hz for full credit. **<u>Examiner's Comments</u>** Most candidates appreciated that the wavelength would be smaller (and many drew a sketch) to produce the next frequency. However, it was difficult to score marks on this if the previous answers were incorrect. Error carried forward is often applied, but in this case major errors will compound and it is not possible to work through the candidates thinking.
			Total	**4**	
9			D	1	**<u>Examiner's Comments</u>** Around one third of candidates were able to identify the correct response; the main difficulty appeared to be that the given angle in the glass was not given relative to the normal (as is usual) and this meant that a common distractor was **A**.
			Total	**1**	
10		i	Zero amplitude / displacement / oscillations / movement (at the nodes)	B1	**Allow** minimum or least for zero throughout **Ignore** references to pressure e.g. min/max pressure **Allow** correct answers in terms of pressure gradients **Penalise** incorrect answers in terms of antinodes **Ignore** correct answers in terms of antinodes **<u>Examiner's Comments</u>** Most candidates were able to appreciate that the stationary wave has nodes and antinodes and correctly relate them to the movement of the particles. Candidates

					were expected to give their responses in terms of the nodes, and responses in terms of the antinodes – such as powder is displaced from the antinodes – does not really answer the question. Several candidates drew a stationary wave on the diagram, with nodes and antinodes at the correct places. As the exemplar below shows, this helps confirm in the candidates mind the variation of the oscillations of the stationary wave. It also helps with subsequent questions; although cannot be given marks itself, candidates are always to be encouraged to make additions to diagrams to help them in supporting their responses.  A candidate drawing on the diagram to assist them to appreciate the vibrations at the nodes and antinodes.
		ii	2 λ = 25 (cm) / λ = 12.5 (cm) $v = 2720 \times 0.125$ $v = 340$ (ms^{-1})	C1 C1 A1	**Maximum** one POT error in this question **Special case: one mark only** for bare 340 (ms^{-1}) with no working **Allow** 2 marks for 170 ms^{-1} if calculated from λ = 6.25 (cm) **<u>Examiner's Comments</u>** This question was well answered by most candidates who were able to correctly appreciate that the given distance of 25cm corresponded to two complete wavelengths of the stationary wave. Encouragingly, very few candidates did not make the cm to m conversion. A small number of candidates thought that the wavelength was the distance between two nodes resulting in an answer of 170 ms^{-1}. Many candidates structured their responses clearly and were able to explain their reasoning.
		iii	$11f_0 = 2.72$ ($\times 10^3$) or 11/4 × 12.5 = $\lambda_o/4$ **or** $\lambda_o = 1.375$ (m) $f_0 = (340 / 1.375) = 247$ (Hz)	C1 A1	**Allow** length of tube = 0.344 (m) **Allow** 250 (Hz) **Allow** ecf on *v* from (c)(ii). **<u>Examiner's Comments</u>** This proved to be a challenging question and only around one fifth of the candidates were able to score any marks. Most successful candidates appreciated that there were 11 quarter wavelengths of the initial wave in the tube and used this to determine the length of the tube, from which they were able to determine the fundamental wavelength and hence the frequency. There are many potential errors

					in this question, however a common incorrect response was 680Hz, calculated from treating the wavelength of the fundamental wave as twice the given distance of 25cm.
			Total	**6**	
11	a		Appearance of nodes / antinodes	B1	**Ignore** the waves don't move **<u>Examiner's Comments</u>** Most candidates did not perform well on this question as they did not use correct scientific terminology to state an observation of stationary waves and used simplistic and superficial language such as 'the waves were not moving' or they lacked the understanding and knowledge of the properties of a stationary wave and described the wave in terms of other properties, e.g. frequency and wave speed which were not credit worthy.
	b	i	**Any acceptable methods e.g.** Note matched to a note produced by a speaker connected to a variable (calibrated) signal generator/ Reduce background sound level **OR** Count the number of oscillations and divide by time taken (from a stopwatch/oscilloscope/slow motion camera) Take many oscillations e.g. 5 or 10/ longer time **OR** Microphone connected to oscilloscope to measure *T* / period <u>and</u> *f* = 1/*T*/period Reduce background sound level **OR** Use a (calibrated) strobe to determine the frequency Dim down the lights (AW) to get the best results	B1 B1	**Allow** vibration generator connected to a variable (calibrated) signal generator **Allow** Adjust signal generator to the fundamental frequency (when a stationary wave is achieved) **<u>Examiner's Comments</u>** The advance information listed that practical skills would be assessed within topic 4.4 waves, but only some candidates were able to describe a simple method to determine the fundamental frequency of the oscillating wire. Marks were still given for a suitable method for determining the fundamental frequency of any oscillating wire, e.g. using a vibration generator and variable signal generator but few candidates developed their method to describe how they would obtain accurate measurements, e.g. measuring the time for 10 oscillations and then dividing by 10 to find the time period *T*, etc. Candidates may not have had the opportunity to carry out this practical skill independently but they should be familiar with the procedure and how measurements are taken to accurately find the fundamental frequency of a stationary wave. Exemplar 2  The wavelength of the fundamental frequency is 2L, so they could have used speed = wavelength x frequency to find fundamental frequency, as when the wavelength is at 2L the fundamental frequency will appear be shown. The had to do speed/2L to find the fundamental freq of the wire. It will be the point where there are nodes only at the supports. [2] Exemplar 2 shows a typical middle range response. This response demonstrates a lack of knowledge and understanding of the practical skills required to measure

					the fundamental frequency as there is no description of a method to measure the time period of a stationary wave.
		ii	**1** 1.24 (m) ($v = f\lambda$) **2** v = 58 × 1.24 v = 72 (m s^{-1}) % uncertainty = [2 × 2.5] + 1.0 + 0.5 (= 6.5) **3** 0.065 × [4 × 58^2 × 9.7 × 10^{-4} × 0.62] absolute uncertainty = 0.53 (N)	B1 C1 A1 C1 A1	**Allow** 1.2(m) **<u>Examiner's Comments</u>** Most candidates performed well on this question as they correctly applied that at the fundamental frequency $\lambda = 2L$. Candidates at the lower end did not recall the wavelength of the stationary wave in terms of the length of wire. **ECF** from (b)(ii)1 **<u>Examiner's Comments</u>** Nearly 80% of candidates correctly selected and applied the formula $v = f\lambda$. Where candidates had incorrectly determined the wavelength at the fundamental frequency, they were given marks for carrying out a correct calculation using their value. Answer to **2sf** only **Allow ECF** 1 mark for %uncertainty of 4% and absolute uncertainty 0.32N **2sf** **<u>Examiner's Comments</u>** About a third of candidates used the information given in the question to determine the percentage uncertainty of 6.5% and used this to find the absolute uncertainty. Some candidates used the maximum and minimum values of the tension to find the absolute uncertainty. Some candidates correctly calculated a value for the absolute uncertainty but did not give their answer to 2 significant figures as the question requested.
			Total	**8**	
12			B	1	**<u>Examiner's Comments</u>** Candidates performed well on this question as most gave the correct answer B by recognising that sound is an example of a longitudinal wave and electromagnetic waves are an example of transverse waves but that they can both form stationary waves.
			Total	**1**	