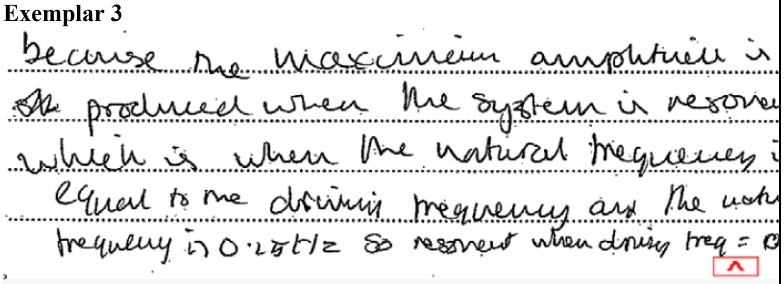
Mark scheme - Oscillations

Question			Answer/Indicative content	Marks	Guidance
1			D	1	<u>**Examiner's Comments**</u> The correct formula here is v_{max} = Aω. This means that to find the angular frequency, ω, you must divide the maximum speed by the amplitude. The amplitude is given in centimetres so that needs to be converted to metres. This gives 24/0.056 = 429 rad s^{-1}, giving the answer D.
			Total	**1**	
2			**B**	**1**	<u>**Examiner's Comments**</u> The damping force is always opposite in direction to velocity. If the displacement is zero, then the speed is greatest and hence the damping force is also greatest in magnitude. The damping force is not always opposite in direction to acceleration, although the displacement must be, according to the definition of SHM.
			Total	**1**	
3			A	1	
			Total	**1**	
4			B	1	
			Total	**1**	
5			**B**	**1**	<u>**Examiner's Comments**</u> In SHM, when x = 0, the object is moving at its fastest and so has maximum KE. This in turn means that the PE must be minimum, eliminating option D. The speed of the object slightly away from the point where x=0 does not increase rapidly nor linearly. This only leaves option B.
			Total	**1**	
6			B	1	
			Total	**1**	
7			**A**	**1**	<u>**Examiner's Comments**</u> About three quarters of all candidates recognised that since = $-\omega^2 2$, the

					angular frequency of this motion was 5. Also, since $\omega = 2\pi f$, the frequency must be equal to $5/(2\pi)$.
			Total	**1**	
8			B	1	
			Total	**1**	
9			B	1	
			Total	**1**	
10			A	1	
			Total	**1**	
11			C	1	
			Total	**1**	
12			Maximum energy is transferred between tower (driver) and sphere when sphere (driven) is at/close to the natural frequency <u>of the tower</u> **or** in this forced oscillation/resonance situation	**B1** **B1**	**allow** causes maximum damping <u>of the tower</u> **or** maximum amplitude <u>of the sphere</u>/AW **allow** AW e.g. sphere must be driven close to/at the natural/resonance frequency <u>of the tower</u> <u>**Examiner's Comments**</u> The answers gave a clear indication as to how well the candidates understood a resonance situation. Many omitted to explain which of the three oscillating elements were acting as drivers and which were driven. The candidate who wrote the answer (exemplar 3) shown here has some understanding of the situation but has failed to communicate it clearly to the reader. **Exemplar 3**  because the maximum amplitude is ~~At~~ produced when the system is resone which is when the natural frequency i equal to the driving frequency and the nat frequency is 0.28Hz so resonant when driving freq = 0 The ball was often quoted as just acting against the tower to reduce the amplitude rather than using the clue at the end of the initial paragraph about the energy drawn from the tower being absorbed by the dampers. Hence the requirement for the ball to be given a large amplitude or absorb the maximum amount of energy.
			Total	**2**	
13	a		Resultant force from springs is proportional to displacement from centre **or** acceleration (of mass) is	B1	

			proportional to displacement from centre.		
			Directed to centre or fixed point.	B1	
	b		Graph correct shape and always positive and suitable scale on kinetic energy axis.	B1	
			Maxima occur at zero displacement times.	B1	
	c	i	Period from graph = 500/3.5 = 143 ms	C1	
		i	Acceleration = $\omega^2 A = (2\pi/0.143)^2 \times 0.006 = 12$ (ms^{-2})	A1	
		ii	KE = $0.5 \times 0.005 \times (2\pi / 0.143 \times 0.006)^2$	C1	
		ii	KE = 1.7×10^{-4} (J)	A1	
			Total	**8**	
14			Force the mass to oscillate with a periodic force. (AW)	B1	
			The mass oscillates at maximum amplitude when the forcing frequency is equal to the natural frequency of the spring−mass system. (AW)	B1	
			Total	**2**	
15			$\omega = (2\pi f =)\ 2\pi \times 0.15$ or 0.3π (= 0.942 rad s^{-1}) $a_{max} = (-\ \omega^2 A =)\ 4\pi^2 f^2 A = 0.050$ $A = 0.05/(2\pi \times 0.15)^2$ $A = 5.6 \times 10^{-2}$ (m)	**C1** **C1** **A1**	ω mark can be implicit in calculation $\omega^2 = 0.88$ or 0.89 using 0.942 or 0.94 **allow** 0.057 (m); **N.B.** answer is 0.053 if use ω instead of ω^2 mark as a TE **max** 2/3 **<u>Examiner's Comments</u>** The words *simple harmonic motion* in the text pointed almost all candidates to use the correct formula. The angular frequency was calculated correctly. Two common errors were to forget to square the value or to give the final answer to only one significant figure rather than a minimum of two.
			Total	**3**	
16			$a_{max} = -\ \omega^2 A$ or $a_{max} = -\ (2\pi f)^2 A$ $\omega = 2 \times \pi \times 5.0 \times 10^8 = 3.1(4) \times 10^9$ (rad s^{-1}) or $10^9\pi$ a_{max} (= $\pi^2 \times 10^{18} \times 4.0 \times 10^{-6}$) = 3.9×10^{13} (m s^{-2})	C1 C1 A1	**Allow** without the minus sign **ECF** from **(a)** **Not** $4.0 \times 10^{12}\pi^2$ **<u>Examiner's Comments</u>**

					The words ‘simple harmonic motion’ in the text prompted almost all candidates to use the correct formula here.
			Total	**3**	
17		i	Correct substitution of T= 2(.0 s) into $T^2 = \frac{4\pi^2}{g}L$ length = 0.99 (m)	C1 A1	**Note:** 1 (m) here cannot score this A1 mark **Examiner's Comments** A large majority of candidates successfully showed that the pendulum length should be 0.99m for a ‘tick’ length of 1.0 seconds. Candidates that attempted the reverse argument, by assuming a length of 1 m and then calculating the corresponding length, were usually unable to show the period of the resulting pendulum was 2.01s. Candidates that showed how to arrive at this period gained full credit.
		ii	Lower g / gravitational field strength / acceleration (of free fall) on Moon. T is longer (on Moon) **and** justified by $T^2 = \frac{4\pi^2}{g}L$ or $T^2 \propto 1/g$ or $\frac{4\pi^2}{g}$ is larger	B1 B1	**Accept** ‘g is a sixth of g on Earth’ AW **Not** gravity (is less) **Examiner's Comments** Many candidates suggested that g is less on the Moon than it is on the Earth, gaining one mark of credit. Most candidates suggested that would mean the period of the pendulum would be larger, but did so without justification from the formula in the question or contradicted themselves by stating that would make the pendulum ‘run faster’.
			Total	**4**	
18		i	Using the graph to determine at least two ratios of the amplitudes.	M1	For example: 2.5/3.0 and 2.1/2.5
		i	Correct statement matching the ratios.	A1	For example: ‘The statement is correct because 2.5/3.0 ≈ 2.1/2.5 ≈ constant. ’
		ii	At time t = 0	M1	
		ii	Oscillator has maximum speed and hence the greatest friction. (AW)	A1	
			Total	**4**	
19			EPE decreases (from bottom to top) GPE increases (from bottom to top)	B1 B1 B1 B1	**Not** EPE becomes 0 (or negative) **Allow** for the first two marking points: description that refers to total potential energy starts at maximum, is minimum at equilibrium point and max again at top, provided total potential energy is stated to be the sum of EPE and GPE

<table>
<tr><td></td><td></td><td></td><td>KE starts at zero, finishes at zero and max at equilibrium point.

Air gains thermal energy / Total energy (of mass and spring) decreases over time</td><td></td><td>Allow as alternative for first three marks:
EPE to KE and GPE in bottom half
EPE and KE to GPE in top half
EPE at start to GPE at top

<u>Examiner's Comments</u>

The best way to answer this question is to plan out what happens to each of the relevant energy types. Exemplar 4 starts off well yet is insufficient. Exemplar 5 is far clearer.

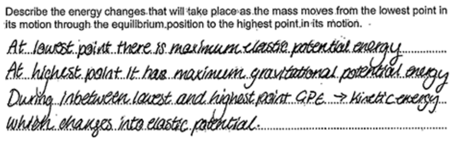
In this case the relevant energy types are elastic potential, gravitational potential and kinetic energy. Candidates often carefully recalled the details of energy changes for a horizontal mass-spring system, which was incorrect.

Earlier in the question, the candidates were told that the spring is always under tension. This means that the elastic potential energy cannot be zero or indeed negative.

At the bottom and the top of the motion, the kinetic energy of the system is zero, as the objects have zero velocity. At the equilibrium position, the kinetic energy of the system is maximum.

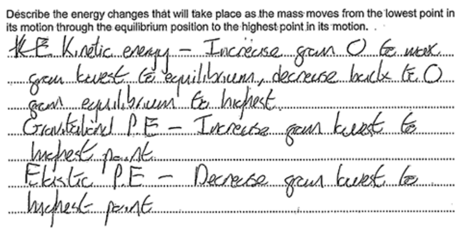
Responses that included merely 'potential energy' were too vague, unless it was clear that the potential energy of this system is the sum of both the gravitational and elastic potential energies.

Exemplar 4


Describe the energy changes that will take place as the mass moves from the lowest point in its motion through the equilibrium position to the highest point in its motion.
At lowest point there is maximum elastic potential energy
At highest point it has maximum gravitational potential energy
During inbetween lowest and highest point GPE → kinetic energy
which changes into elastic potential.

The first 2 statements in this response are true yet not enough. The third statement is untrue, as it implies that GPE is decreasing (and so contradicts the second statement) and also states that the elastic potential energy is increasing. Zero marks.

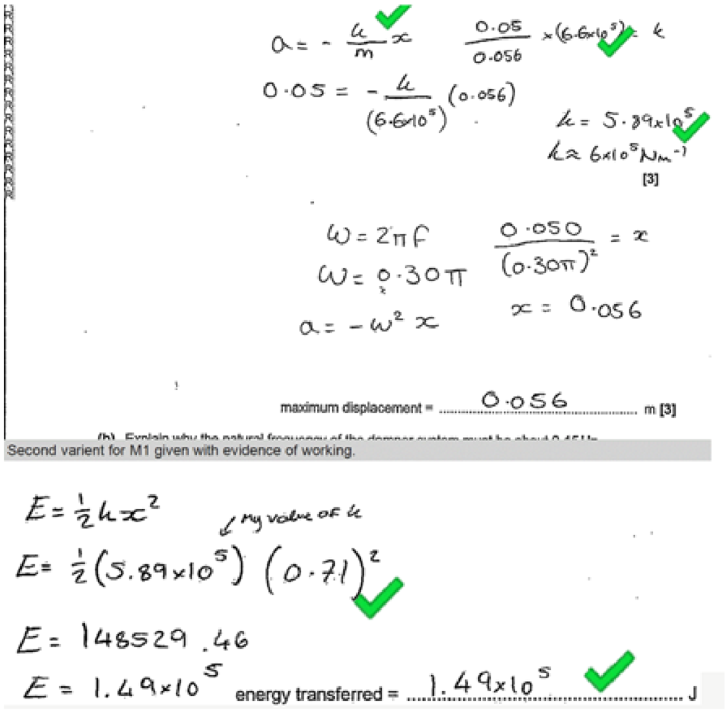
Exemplar 5


Describe the energy changes that will take place as the mass moves from the lowest point in its motion through the equilibrium position to the highest point in its motion.
KE Kinetic energy – Increase from 0 to max from lowest to equilibrium, decrease back to 0 from equilibrium to highest.
Gravitational P.E – Increase from lowest to highest point
Elastic P.E – Decrease from lowest to highest point

This response is separated out into the 3 main energy types. The changes for each of the types is correct. The only thing they haven't mentioned is that the total energy of the system will decrease because of the damping effect of the air. 3 marks.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>4</td><td></td></tr>
</table>

20			**Accept any sensible and successful method.** **Stroboscope:** Any two from • Use of stroboscope of known frequency or period • Photograph to capture several positions on one picture • Measure displacement from centre using a scale put behind the mass. **or** **Motion sensor:** Any two from • Motion sensor connected to data logger which sends information on displacement and time to computer. • Sensor placed close to moving mass to eliminate reflections from other objects. • Small reflector attached to mass.	B1 × 2	Video camera with freeze frame facility, where time between frames is known. Apply marking points as for the stroboscope.
			Safeguards to ensure accuracy **Stroboscope:** Any two from • Use frequency such that positions of mass are close together on photograph. • distance scale close to oscillating mass or camera set back from mass to reduce parallax. • Camera should be directed at equilibrium point or at 90° to oscillation. **or** **Motion sensor:** Any two from • Any attached reflector should not cause damping. • Motion sensor directed along line of oscillation or motion sensor signal blocked by supports so	B1 × 2	

			must be as near to line of oscillation as possible. • Use thin supports to reduce reflections.		
			Total	**4**	
21		i	5 (mm).	A1	
		ii	1.0 mark on scale at peak of curve.	B1	minimum requirement for mark: 0 to 3 Hz marked at 1 Hz intervals along axis.
		iii	approx. same (or slightly lower) resonance frequency.	B1	
		iii	smaller amplitude/broader peak *but curves must not cross* and passes through (0, 5 mm).	B1	
			Total	**4**	
22		i	$\omega^2 = k/m$ **or** $(2\pi f)^2 = k/m$ **or** $kA = ma_{max}$ $k =(m4\pi^2f^2)= 6.6 \times 10^5 \times (2\pi \times 0.15)^2$ **or** ($k= ma_{max}/$**A**) = $6.6 \times 10^5 \times 0.05/0.056$ $k = 5.9 \times 10^5$ (N m^{-1})	**C1** **M1** **A1**	**allow** ω or ω^2 = 0.88 or 0.89 quoted from **(a) ecf** value of A from **(a)** as this is a 'show that' question some definite evidence of working must be shown. **not** $k = 6 \times 10^5$ **allow** answer to 2 or more SF.
		ii	$E = ½kA^2 = = 0.5 \times 5.9 \times 10^5 \times 0.71^2$ $E = 1.5 \times 10^5$ (J)	**C1** **A1**	**allow** value from (c)**(i)** or 6; **or** a = (k/m)A , F = ma, E = ½F*A* **accept** 1.48 to 1.51 or value from **ecf** **special case:** give 1/2 for E = 3(.0) × 10^5 (J) where **it is clear that** 2k has been used as the spring constant **<u>Examiner's Comments</u>** The exercise in this section completed successfully by most candidates was to perform standard calculations stating correct formulae and showing clear working to determine the required quantities. The example (exemplar 4) shown here is of a typical neat script. The most common error was to forget to square quantities in part (ii) or to use the amplitude calculated part (a) rather than the figure given in the stem of this part. **Exemplar 4**

					 $a = -\frac{k}{m}x$ $\frac{0.05}{0.056} \times (6.6\times10^5) = k$ $0.05 = -\frac{k}{(6.6\times10^5)}(0.056)$ $k = 5.89\times10^5$ $k \approx 6\times10^5 Nm^{-1}$ [3] $\omega = 2\pi f$ $\omega = 0.30\pi$ $a = -\omega^2 x$ $\frac{0.050}{(0.30\pi)^2} = x$ $x = 0.056$ maximum displacement = 0.056 m [3] Second varient for M1 given with evidence of working. $E = \frac{1}{2}kx^2$ ↙my value of k $E = \frac{1}{2}(5.89\times10^5)(0.71)^2$ $E = 148529.46$ $E = 1.49\times10^5$ energy transferred = 1.49×10^5 J
			Total	**5**	
23	a	i	$a = -\omega^2 x$ seen Suitable linking $a = -\omega^2 x$ and either $\omega = 2\pi f$ or $\omega = 2\pi/T$ with substitution $f = 1.41$ (Hz)	B1 M1 A1	e.g. $4\pi^2 f^2 = 78.3$ or $f = \text{sqrt}(3.6/4\pi^2 \times 4.6 \times 10^{-2})$ or $f = 8.85/2\pi$ or $T = 0.71...$ **Allow** f = 1.408... (Hz)
		ii	$A = \frac{x}{\cos \omega t}$ or $A = \frac{4.6\times10^{-2}}{\cos(2\times\pi\times1.4\times6.}$ (Any subject) A = 0.057 (m)	M1 A1	**Not**: sine for cosine. **Note** A = 0.090(4)(m) if 1.41 used **Note** A = 0.0796 (m) if 1.408 used **Allow** 1 mark for cosine used with calculator in degrees **<u>Examiner's Comments</u>** As the mass is pulled down before release, the mass is away from the equilibrium position. This means that the sine relationship between displacement and time cannot be correct. Many candidates got this idea correct. The relationship $x = A\cos(\omega t)$ requires that the value of ωt is expressed in radians. This meant that to calculate the amplitude correctly, the calculator has to be in radians mode, rather than degrees mode.
	b	i	(Smooth) curve showing amplitude increases and then decreases maximum at 1.4 Hz by eye	B1 B1	**Not:** more than 1 peak **Allow:** asymptote instead of peak **<u>Examiner's Comments</u>**

					The correct shape for Question 18(c)(i) is a standard resonance curve. The natural frequency of this system is 1.4 Hz, as stated in Question 18(a). This means that the peak of the curve should come at 1.4 Hz. The curve for Question 18(c) needed to be of lower amplitude throughout the frequency range (not including at 0 Hz). Some candidates put the peak of curve D at the same frequency as curve K and others put the peak of curve D slightly to the left. Both were given the mark.
		ii	Curve similar shape yet lower at all non-zero f points with peak shifted slightly to left (of 1.4 Hz)	B1	**Allow:** curve without shifted peak i.e. peak at 1.4 Hz ECF their K curve **Examiner's Comments** The correct shape for Question 18(c)(i) is a standard resonance curve. The natural frequency of this system is 1.4 Hz, as stated in Question 18(a). This means that the peak of the curve should come at 1.4 Hz. The curve for Question 18(c) needed to be of lower amplitude throughout the frequency range (not including at 0 Hz). Some candidates put the peak of curve D at the same frequency as curve K and others put the peak of curve D slightly to the left. Both were given the mark.
		iii	Bridge close to resonance if frequency of driver is close to natural frequency of bridge (Close to resonance) giving larger amplitude which causes damage or other named consequence	B1 B1	**Allow:** footfall/people walking/wind for driver **Allow:** resonance (occurs) when frequency of driving force is at natural frequency of bridge **Allow**: Maximum for larger **Examiner's Comments** Many candidates linked the possibility of a driving force, such as footsteps or the wind, giving a driver frequency at or near the natural frequency of a bridge and that this phenomenon is known as resonance. The second mark was for a link of the resonance idea of maximum amplitude to a consequence, such as a bridge shaking itself apart or being too unstable for use.
			Total	**10**	
24		i	$\omega^2 = g/L$ $\omega = \frac{2\pi}{T}$ Correct substitution $\frac{4\pi^2}{T^2} = \frac{g}{L}$ and rearranging to give correct expression	M1 M1 A1	**Note:** Both M1 marks are required to score this A1 mark **Examiner's Comments** Most students had considerable success in deriving the required expression.
		ii	Transfer of **energy** to air / retort stand (because of air resistance /	B1	**Allow** 'loss of energy from pendulum (due to friction)' **Allow** 'work done' for 'energy'

			friction) No effect on *T* (as *T* is independent of amplitude in SHM for small amplitude oscillations of pendulum)	**B1**	**Allow** 'isochronous' **Examiner's Comments** A pleasingly large proportion of students remembered that specification point 5.3.1 (f) states that the period of a simple harmonic oscillator is independent of its amplitude. A similarly large proportion referred to damping or action of the drag force but fell slightly short of the idea that the effect of that force is to reduce the energy stored in the pendulum.
			Total	**5**	
25		i	$\omega = 2\pi \times 1.2$	C1	
		i	($a_{max} = \omega^2 A$); $a_{max} = [2\pi \times 1.2]^2 \times 3.0 \times 10^{-2}$	C1	
		i	maximum acceleration = 1.7 (m s^{-2})	A1	
		ii	Correct curve with peak of greater amplitude.	B1	
		ii	Peak slightly right of first curve.	B1	**Allow** graph peaking at 1.2 (Hz)
			Total	**5**	
26			**Level 3 (5–6 marks)** Clear description including steps to obtain high quality data **and** analysis *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)** Clear description **and** some analysis *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 **and** analysis **Or** limited description *The information is basic and communicated in an unstructured way.*	**B1 × 6**	**Indicative scientific points may include:** **Experiment** **Description** • Pendulum string clamped / fixed (can be shown on diagram) • Use a stopwatch to determine time period *T* • Time multiple oscillations to determine *T* • Use a ruler to measure *L* • Vary length *L* and determine *T* **Quality of Data** • Method used to ensure small oscillations • Small angles i.e. <10 degrees • Idea of fiducial mark • Start / stop timing at the centre of the oscillation • Measure from the fixed point to the centre of the bob **Analysis**

			The information is supported by limited evidence and the relationship to the evidence may not be clear. **0 marks** No response or no response worthy of credit.		• Correct plotting of graph, e.g. T^2 against L or T against $\sqrt{L}$ or lg T against lgL • Analysis of data table showing T^2/L = constant • Expect a straight line through the <u>origin</u> • Correct gradient of the line e.g. $4\pi^2/g$ Use only L1, L2 and L3 in RM Assessor. **Examiner's Comments** While a small number of candidates described the incorrect experiment (such as masses on a spring or circular motion) most candidates made excellent attempts to describe the experiment and the ensuing analysis. References to even the most basic equipment are essential, such as measuring lengths with a ruler and periods of time with a stopwatch or other suitable timer. Candidates that did neither could not score higher than Level 1. Level 3 responses included ideas about achieving high quality data, such as use of a fiducial mark, starting the oscillation count (and hence the timer) at the midpoint where the pendulum bob is fastest, stating a suitable small angle of ten degrees or less and how to achieve that consistently with a protractor and by measuring the length of the string from the suspension point to the centre of the bob. By far the preferred method of analysis leading to verification of the relationship was plotting a graph of T^2 against L and expecting the trend to be not only straight but also through the origin with a gradient of ($4\pi^2/g$). An acceptable alternative was to suggest calculating several values of (T^2/L) and demonstrating that ratio to be constant and equal to ($4\pi^2/g$). Note that writing 'Plot a graph of T^2/L' is not an acceptable short hand for 'plot T^2 on the y-axis and L on the x-axis.
			Total	**6**	
27	a	i	$a = (-)\ 4\pi^2 f^2 x = 4 \times 9.87 \times 4900 \times 0.004$	C1	**allow** 774 (m s^{-2})
		i	a = 770 (m s^{-2})	A1	
		ii	**1** sketch showing one wavelength and 140 (Hz)	B1	both sketch and value required for 1 mark
		ii	**2** driving force is around nodal point / AW;	B1	**max** 3 of the 4 marking points
		ii	points either side of nodal point try to move in opposite directions when force in one direction / AW;	B1	
		ii	move magnet to antinodal point; ¼ of distance between clamps	B1	**not** increase current

	b	i	*f α* √T so f = 70/√2 = 49 or 50 Hz	B1	
		ii	**1** μ increases / goes up by 0.4%	B1	**allow** +0.4% NOT 0.4%
		ii	**2** 0.2%,	B1	**or** half of answer to **(ii)1**
		ii	f is lower because μ is bigger and μ is on the bottom of the formula	B1	**or** greater inertia present with same restoring force / other physical argument
			Total	**10**	
28		i	$a = 4\pi^2 f^2 \times$	C1	condition for SHM
		i	so $k = (m4\pi^2 f^2) = 1.7 \times 10^{-27} \times 4 \times 9.87 \times 43.7 \times 10^{26}$	B1	substitution
		i	k = 292 (N m^{-1})	A1	**ecf** if incorrect mass used
		ii	(N2 gives) $F_H = m_H a_H$ and $F_I = m_I a_I$	B1	**allow** total momentum = 0 at all times
		ii	(N3 gives) $F_H = F_I$ *can be implicit*	B1	SHM gives $v = 2\pi f x_{max}$
		ii	SHM gives a α (−)x	B1	so $m_H X_H = m_I x_I$
		ii	hence $x_H/x_I = a_H/a_I = m_I/m_H = 127$	B1	**accept** $127 = x_H/x_I \approx 10/0.08 = 125$
			Total	**7**	
29		i	$x = A\cos(\omega t)$ **or** $x = A\cos(2\pi ft)$ $x = 2.0\cos(2\pi \times 1.4 \times 0.60)$ displacement = 1.1 (cm)	C1 C1 A1	**Note** : Treat use of sine as **TE** **Note** answer is 1.07 (cm) to 3SF **Note** answer if calculator left in degrees of 1.99cm scores 2 marks.
		ii	(v_{max} =) 2π × 1.4 × 0.02 maximum speed = 0.18 (m s^{-1})	C1 A1	
		iii	**1** Larger (amplitude) **2** Same (period)	B1 B1	
			Total	**7**	
30	a		3.6 ± 0.4 ($m^2\ s^{-2}$)	B1	
	b	i	Data point and error bar correctly plotted	B1	**Allow** ecf from previous part.
		ii	* **Level 3 (5–6 marks)** Detailed analysis of the graph clearly linked to the principle of conservation of energy, including determination of the value of *g* and	B1 × 6	**Explanation** 1. Principle of conservation of energy used to derive relationship. 2. $mgh = ½ mv^2$ or $v^2 = 2gh$

			the related uncertainty in the answer. *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)** Analysis of the graph linked to kinetic energy and / or potential energy, with an attempt to find the value of *g*. Mention of where one would find uncertainties in the answer but without analysis. *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)** Line of best fit drawn and gradient attempted. Mention of energy and / or where uncertainties may occur. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		3. A graph of v^2 against *h* will be a straight line (through the origin). 4. Gradient of line = 2*g*. **Determination** 1. Line of best fit drawn through all data points. 2. Gradient in the range 17 to 21 (m^2 s^{-2}). 3. *g* determined correctly from the gradient. **Uncertainty** 1. Worst line of fit drawn. 2. Correct attempt to determine the uncertainty.
			Total	**8**	
3 1		i	sin **or** cos wave with 1.5 wavelengths (between **C** and **R)** y-axis showing scale, i.e. (amplitude) 2.(0) × 10^{-6} (m) correct scale on x-axis showing λ = 0.2 (m) **X** and **Y** labelled at adjacent intercepts on x-axis	**B1** **B1** **B1** **B1**	unit must be present, e.g 10^{-6} m **NOT** if axis labelled time **Examiner's Comments** Most candidates correctly labelled the scale on the displacement axis of the sinusoidal graph that they drew. The points where the air particles were moving the fastest were also well known. Fewer labelled *distance* on the x-axis, many incorrectly writing *time.* Only the better candidates marked the correct scale on this axis and very few indicated that there were 1.5 wavelengths between the points **C** and **R.**

		ii	1 $v = A\omega$ **or** $2\pi fA$ $v = (2 \times 10^{-6} \times 2 \times 3.14 \times 1.7 \times 10^{3} =)$ 2.1×10^{-2} (m s^{-1}.) 2 $\frac{1}{2}Mv^2 = 3/2\ RT$ and $T = 290$ $v = \sqrt{(3 \times 8.31 \times 290 / 0.029)}$ $v = 5(.0) \times 10^2$ (m s^{-1}.)	C1 A1 C1 A1	**or** $\frac{1}{2}mv^2 = 3/2\ kT$ so $v^2 = 3\ (k / m)\ 290$ **N.B. remember to record a mark out of 4 here** **Examiner's Comments** Answers were generally well structured into two sections, one for each experiment. A few candidates thought they could measure the wavelength on the oscilloscope screen. In experiment (a) most understood that the phase difference between the two oscillations at the microphone changed as one speaker was moved away. Explanations often muddled *path* and *phase* difference or referred to *nodes* and *antinodes* detected by the microphone. Some candidates misinterpreted the experiment moving the microphone to detect interference fringes, allowing the double slits formula to be used to find the wavelength. Others thought that Doppler shift was applicable. For experiment (b) many candidates used *maxima* and *minima* in place of *antinodes* and *nodes* although most recognised this to be a *standing* wave situation. Quite a few candidates ignored the instruction about reducing the uncertainty. The best candidates suggested reducing the frequency to reduce the percentage uncertainty in the wavelength measurement.
			Total	**8**	