PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



MARK SCHEME

TOPIC 13: OSCILLATIONS

SCORE	PERCENTAGE
/220	%

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Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Determination of gradient (1) • Re-arrangement of $T = 2\pi\sqrt{\frac{l}{g}}$ (1) • Algebra to show $T^2 = -\frac{4\pi^2}{g}d + \frac{4\pi^2}{g}h$ (1) • Gradient $= (-)\frac{4\pi^2}{g}$ (1) • g = 9.6 m s^{-2} [accept 9.5 → 9.7 m s^{-2}] (1)	$T^2 = \frac{4\pi^2}{g}l$ $T^2 = \frac{4\pi^2}{g}(h-d)$ $T^2 = -\frac{4\pi^2}{g}d + \frac{4\pi^2}{g}h$ Example of calculation gradient $= \frac{(12.1-9.2)\text{ s}^2}{(0.00-0.70)\text{ m}}$ $= -4.1\text{ s}^2\text{m}^{-1}$ $\therefore g = \frac{4\pi^2}{4.1\text{ s}^2\text{m}^{-1}} = 9.6\text{ m s}^{-2}$	5

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• discards value for l_3 (1) • l_m=85.7 (cm) (1)	MP2: answer to 1 d.p. only Example of calculation $l_m = \frac{85.5+86.0+85.5}{3} = 85.7$ cm	2
(ii)	• Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ (1) • T=1.86 s (1)	ECF from (i) MP2: accept T= 1.9 s Example of calculation $T = 2\pi\sqrt{\frac{\ell}{g}}$ $= 2\pi \times \sqrt{\frac{0.857\text{ m}}{9.81\text{ m s}^{-2}}} = 1.86\text{ s}$	2

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
*	See table below	See table below	

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Indicative content:

IC1 Alternating p.d. causes an alternating current in the coil

IC2 Current carrying conductor in a magnetic field experiences a force

IC3 Current is alternating, so force changes direction with current (same frequency)
Or the alternating current drives the cone at the frequency of the p.d.

This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The table shows how the marks should be awarded for indicative content and structure and lines of reasoning.

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5–4	3
3–2	2
1	1
0	0

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Alternative to first 3 indicative content points:

IC1 Current in coil causes a magnetic field

IC2 Current is alternating so field changes direction with current (same frequency)

IC3 Field interacts with permanent magnet's field so coil experiences oscillating force

	IC4 The loudspeaker forces the box into oscillation IC5 (At certain frequencies) the frequency of oscillation equals the natural frequency of oscillation of the air in the box IC6 Maximum energy is transferred and the amplitude of vibration of the box increases	IC6 Resonance occurs and the amplitude of vibration of the box increases	6

Q4.

Question Number	Acceptable answer	Additional guidance	Mark
	D	The only correct answer is **D** because when damping is decreased maximum amplitude increases and the frequency at which it occurs increases A is not correct because it states that they both decrease B is not correct because it states that the maximum amplitude decreases C is not correct because it states that the frequency decreases	1

Q5.

Question Number	Answer	Mark
	D	1

Q6.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• new spring constant = 11 N m^{-1}	(1)	Example of calculation: $k = 22/2 = 11\ \text{N m}^{-1}$	
	• Use of $T = 2\pi\sqrt{\frac{m}{k}}$	(1)	$T = 2\pi\sqrt{\frac{0.12\,\text{kg}}{11\,\text{N m}^{-1}}} = 0.66\,\text{s}$	
	• Use of $f = 1/T$	(1)		
	• f = 1.5 Hz	(1)	f = 1/0.66 s = 1.5 Hz	4

Q7.

Question Number	Answer	Mark
	D	1

Q8.

Question Number	Answer	Mark
	C	1

Q9.

Question Number	Answer	Mark
	D	1

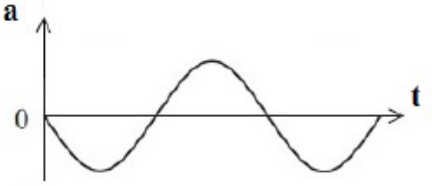
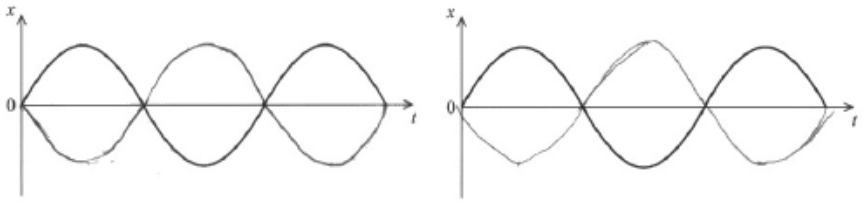
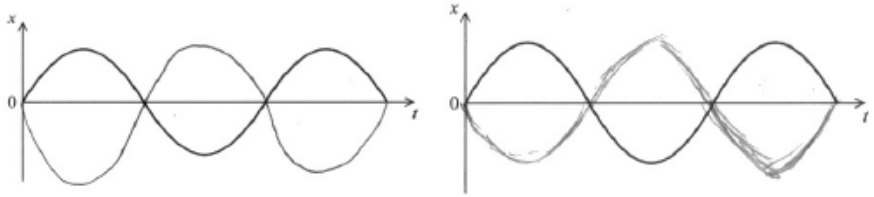
Q10.

Question Number	Answer	Mark
	B	1

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Maximum value of a read from graph [8 m s^{-2} → 9 m s^{-2}] **(1)** • Value for period determined from time for at least 3 cycles **(1)** • Use of $\omega = \frac{2\pi}{T}$ **(1)** • Use of $a = (-)A\omega^2 \cos \omega t$ **(1)** • A = 0.33 m, so report is correct **(1)** [Accept value for A in range 0.25 m → 0.40 m with appropriate conclusion]	Example of calculation $T = \frac{(89.2 - 81.0)\text{ s}}{7} = 1.2\text{ s}$ $\omega = \frac{2\pi}{1.2\text{ s}} = 5.2\text{ rad s}^{-1}$ $x = \frac{a}{\omega^2} = \frac{9\text{ m s}^{-2}}{(5.2\text{ rad s}^{-1})^2} = 0.33\text{ m}$	**5**

Q12.

Question Number	Answer	Mark
(b)(i)	Acceleration is: • proportional to displacement from equilibrium position (1) • (always) acting towards the equilibrium position **Or** idea that acceleration is in the opposite direction to displacement (1) **Or** Force is: • proportional to displacement from equilibrium position (1) • (always) acting towards the equilibrium position **Or** idea that force is a restoring force e.g. "in the opposite direction" (1) [accept undisplaced point/fixed point/central point for equilibrium position] [An equation with symbols defined correctly is a valid response for both marks. e.g. $a \propto -x$ **or** $F \propto -x$]	2
(b)(ii)	Minus sine curve with constant amplitude (1) a  Examples of acceptable graphs:  Examples of unacceptable graphs:  	1

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	A		1

Q14.

Question Number	Answer	Mark
	C	1

Q15.

Question Number	Answer	Mark
	A	1

Q16.

Question Number	Answer	Mark
	C	1

Q17.

Question Number	Answer	Mark
	B	1

Q18.

Question Number	Acceptable answers	Additional guidance	Mark
	An explanation that makes reference to: **Either** • The oscillating frame causes the lead spheres to deform plastically **(1)** • And this removes energy from the oscillating frame **(1)** • So the amplitude of oscillations decrease with time as shown by the graph **(1)** **OR** • Spheres collide/vibrate **(1)** • Hence energy dissipated **(1)** • So the amplitude of oscillations decrease with time as shown by the graph **(1)**		**3**

Q19.

Question Number	Answer	Mark
	B	**1**

Q20.

Question Number	Answer	Mark
	D	**1**

Q21.

Question Number	Answer	Mark
(i)	Identification of weight and force from cone, F_c, as the two forces acting on the sand **(1)** Weight $- F_c = m\omega^2 x$ **(1)** So as x increases, F_c decreases, sand loses contact with cone when $F_c = 0$ **(1)**	3
(ii)	Resultant force equated to weight **Or** acceleration equated to g **(1)** Use of $\omega = 2\pi f$ **(1)** $f = 32$ Hz **(1)** <u>Example of calculation:</u> $mg = m\omega^2 x_0$ $\omega = \sqrt{\frac{g}{x_0}} = \sqrt{\frac{9.81\,\text{m s}^{-2}}{0.25\times10^{-3}\,\text{m}}} = 198\,\text{rad s}^{-1}$ $f = \frac{\omega}{2\pi} = \frac{198}{2\pi} = 31.5\,\text{Hz}$	3

Q22.

Question Number	Answer	Mark
*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Current carrying conductor in a magnetic field **(1)** Coil experiences a force **(1)** Current is alternating, so force changes direction with current (same frequency) **(1)** **Or** Current in coil causes a magnetic field **(1)** Current is alternating so field changes direction with current (same frequency) **(1)** Field interacts with permanent magnet's field so coil experiences oscillating force **(1)**	3

Q23.

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*</td>
<td>This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative points seen in answer</td><td>Number of marks awarded for indicative points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
Indicative content:

As magnet A moves, its coil experiences a change of magnetic flux (linkage)
The change in magnetic flux linkage induces an emf in the coil
The (induced) emf causes a current in both coils
The current in the second coil causes a force to act on magnet B, driving magnet B into oscillation
Because both mass-spring systems have the same period/frequency
Resonance occurs (and magnet B oscillates with increasing amplitude)

</td>
<td>The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><td></td><td>Number of marks awarded for structure and lines of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkage between points and is unstructured</td><td>0</td></tr>
</table>
Linkage Marks

IC points 1 – 4
Three of these points could score one linkage mark

IC points 5 & 6 could score one linkage mark</td>
<td>6</td>
</tr>
</table>

Q24.

Question Number	Acceptable answer	Additional guidance	Mark
	D	The only correct answer is **D** because the frequency is inversely proportional to the square root of length and independent of the mass, so if length is quadrupled, frequency is halved to $f/2$ A is not the correct answer because it is $4f$ B is not the correct answer because it is $2f$ C is not the correct answer because it is f	1

Q25.

Question Number	Answer	Mark
	B – 0.40 Hz	**1**
	Incorrect Answers: Correct method: $f = 24 \div 60\ s = 0.40\ Hz$ A – uses 1 minute ÷ 24 C – uses 60 s ÷ 24 D – uses 24 ÷ 1 minute	

Q26.

Question Number	Acceptable answers		Additional guidance	Mark
	• Use of $T = 2\pi\sqrt{(l/g)}$	**(1)**	Example of calculation $T = 2\pi\sqrt{(l/g)}$ $T = 2\pi\sqrt{(0.43 / 9.81)}$ $= 1.32$ s $T = 2\pi\sqrt{(0.67 / 9.81)}$ $= 1.64$ s $T = (1.32\ s + 1.64\ s) / 2 = 1.48$ s $f = 1 / 1.48\ s = 0.68$ Hz	**4**
	• Apply factor of 2 correctly for 2 half cycles	**(1)**		
	• Use of $f = 1/T$	**(1)**		
	• $f = 0.68$ Hz	**(1)**		

Q27.

Question Number	Answer	Mark
	C	1

Q28.

Question Number	Answer		Mark
(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) (Hooke's Law:) for a spring, force is proportional to extension **Or** $F = k\Delta x$	**(1)**	
	An extension of the spring causes a force towards the equilibrium position **Or** (resultant force towards the equilibrium position, so) $ma = -k\Delta x$	**(1)**	
	Condition for shm is restoring force [acceleration] is proportional to displacement (from equilibrium position) [QWC question, so max 2 if equations given with no further explanation]	**(1)**	**3**
(b)	Use of $a = -\omega^2 x$	**(1)**	
	Use of $T = \frac{2\pi}{\omega}$	**(1)**	
	$T = 1.55$ (s)	**(1)**	**3**
	[Credit use of F = k Δx and use of $T = 2\pi\sqrt{\frac{m}{k}}$ for first two marking points] Example of calculation: $\omega = \sqrt{\frac{0.49\ \text{m s}^{-2}}{3.0\times10^{-2}\ \text{m}}} = 4.04\ \text{s}^{-1}$ $T = \frac{2\pi}{4.04\ \text{s}^{-1}} = 1.55\ \text{s}$		
(c)(i)	Damped / damping [Do not accept critical/heavy damping]	**(1)**	**1**
(c)(ii)	Forced / driven	**(1)**	**1**
(c)(iii)	Resonance	**(1)**	
	f = 0.65 Hz [accept s^{-1}] [0.625 Hz if show that value is used, 0.64 Hz if unrounded value used]	**(1)**	**2**
	Example of calculation: f = 1/1.55 s = 0.645 Hz [allow 2nd mark if they use either their value from (b) or 1.6 s]		
(d)	(With a smaller mass baby) the natural frequency of oscillation would increase **Or** The natural frequency of the system would increase		

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	Or (1) The periodic time of the system would decrease Smaller mass baby would have to kick at a higher frequency (to force system into resonance) (1) [accept larger mass baby would have to kick at a lower frequency]	**2**
	Total for question	**12**

Q29.

Question Number	Acceptable Answer	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The table shows how the marks should be awarded for indicative content and structure and lines of reasoning. **Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points** 6 – 4 5–4 – 3 3–2 – 2 1 – 1 0 – 0 **Number of marks awarded for structure of answer and sustained line of reasoning** Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout – 2 Answer is partially structured with some linkages and lines of reasoning – 1 Answer has no linkages between points and is unstructured – 0	**IC Points / IC Mark / Max linkage mark avail. / Max final mark** 6 / 4 / 2 / **6** 5 / 3 / 2 / **5** 4 / 3 / 1 / **4** 3 / 2 / 1 / **3** 2 / 2 / 0 / **2** 1 / 1 / 0 / **1** 0 / 0 / 0 / **0** IC1: accept references to flux cutting Alternative indicative content for IC4 – IC5 4. The current is in the magnetic field produced by the magnet 5. The current experiences a magnetic force	**6**

	Indicative content: 1. Removing the magnet from the ring changes the magnetic flux (linked with the ring) 2. This induces an e.m.f. (in the ring) 3. E.m.f. causes a current in the ring 4. Which produces a magnetic field 5. The magnetic fields interact/combine 6. This opposes the change, causing an attractive force to act		

Q30.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following: • (Magnetic levitation) reduces frictional forces (acting on the train as it moves) **(1)** • This reduces the work done against friction **Or** this makes it more efficient **Or** there is less time to reach maximum speed **Or** there is a higher maximum speed **(1)**	MP1: accept removes/no frictional forces MP2: accept there is less fuel used **Or** less energy is wasted	**2**

Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	• There is (damping due to) air resistance and this (damping) force is the same for both (since they have the same shape, area and speed initially) (1) • For large mass the force due to air resistance produces a smaller negative acceleration since $a = F/m$ (1) • The speed will decrease less for each swing, so there is less effect on the amplitude **Or** It will take longer for the (maximum) speed to decrease (to zero) so the pendulum will oscillate for a longer time (1) **OR** • There is air resistance and the force is the same for both (1) • The work done by air resistance per swing is the same for both masses (1) • Initially the larger mass has greater quantity of energy shared between its kinetic and potential energy stores, so the proportion of KE transferred to the thermal energy store of the sphere and the surroundings is less per swing, so there is less effect on the amplitude **Or** Larger mass has greater total energy so fraction dissipated per swing is smaller so the pendulum will oscillate for a longer time (1)		3

	OR There is air resistance and this force is the same for both (1) • For both masses the change in momentum per swing is the same (1)		

	• The larger mass has greater initial momentum so it will take longer for the (maximum) momentum to decrease (to zero) so the pendulum will oscillate for a longer time (1)		

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation that makes reference to the following: • The astronauts are in free fall in the space craft **Or** The acceleration of the astronauts and the space station are the same **(1)** • So there is no contact/reaction force acting on them **(1)**	For MP2, accept a statement that the gravitational force (weight) is the only force acting upon them **Or** all of their weight is used to provide the centripetal force /acceleration	**2**

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	• There is damping **Or** resistive forces act on the flamingo **(1)** • Energy is removed from the oscillating system (and the amplitude decreases) **(1)**		**2**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is **D** because velocity is equal to the gradient of the displacement-time graph A is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as proportional to −1 times the displacement B is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as −1 times the gradient C is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as proportional to the displacement		1

Q5.

Question Number	Answer	Mark
	The only correct answer is B because acceleration is proportional to force, so the acceleration graph would have the shape of the force graph. The acceleration at the start is zero, so the velocity graph must have an initial gradient of zero. For the acceleration to be positive in the first quarter cycle the velocity must be increasing. This graph has an initial gradient of zero and increasing velocity. A the initial gradient is not zero C the initial gradient is not zero D the velocity in the first quarter cycle is decreasing	1

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Timing a large number of oscillations minimised the percentage uncertainty in the measurement (1) • Repeating each timing measurement and calculating a mean minimised the effect of random errors (1) • Taking a repeat measurement allowed a check for gross timing errors. (1)		3

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• Ignoring mass of holder / spring when determining the oscillating mass (1)		1
(ii)	• Using a data logger (and light gate) would eliminate reaction time (1) • So the uncertainty in the measurement (of the time) would be reduced (1) • Not easy to measure timings for multiple swings/oscillations with a data logger (1)		3
(iii)	• Identify gradient as $\frac{4\pi^2}{k}$ (1) • Determine gradient of graph (1) • $k = 17.8\ \text{N m}^{-1}$ [17.5 → 18.5] (1)	Example of calculation Gradient = $2.21\ \text{s}^2\ \text{kg}^{-1}$ $k = \frac{4\pi^2}{2.21\ \text{s}^2\ \text{kg}^{-1}}$ $= 17.8\ \text{N m}^{-1}$	3

Q8.

Question Number	Answer	Mark
	C	1

Q9.

Question Number	Answer	Mark
	B	1

Q10.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $W = mg$ (1) • Use of $\Delta F = k\Delta x$ (1) • Use of $T = 2\pi\sqrt{\frac{m}{k}}$ (1) • Use of $f = \frac{1}{T}$ (1) • $f = 1.7$ (Hz), so claim is incorrect. (1)	Example of calculation: $k = \frac{65 \times 10^{-3}\text{kg} \times 9.81\ \text{N kg}^{-1}}{0.085\ \text{m}} = 7.50\ \text{N m}^{-1}$ $T = 2\pi\sqrt{\frac{65 \times 10^{-3}\ \text{kg}}{7.50\ \text{N m}^{-1}}} = 0.585\ \text{s}$ $f = \frac{1}{T} = \frac{1}{0.585\ \text{s}} = 1.71\ \text{Hz}$	5

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• no net force on bridge (1) • no net moment of force about any point (1)	Alternative wording that implies these 2 points will be accepted	**(2)**
(a)(ii)	• use of $W = mg$ to find the weight of the bridge (1) • use of moment = $F x$ (1) • applies principle of moments (1) • F_A = 43610 N (1) • applies equilibrium of forces or applies principle of moments about a different point to obtain F_B = 45990 N (1)	<u>Example of calculation:</u> W = mg = 8500 kg × 9.8 N kg^{-1}= 83300 N Taking moments about A, Clockwise moments = (1500 N × 4 m) + (4800 N × 6.5 m) + (83300 N × 9.5 m) Anticlockwise moments = F_A × 19 m 19 N × F_A = 828550 Nm F_A = 828550 Nm/19 m = 43610 N $F_A + F_B$ = 1500 N + 4800 N + 83300 N F_B = 89600 N – 43610 N = 45990 N	**(5)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	• resonance occurs when the bridge is forced into oscillation at its natural frequency (1) • this results in an increasing amplitude of oscillation of the bridge, which may damage the bridge (1)		**(2)**
(b)(ii)	• energy was transferred from the oscillating bridge to the dampers (1) • this energy was dissipated in the dampers (and not returned to the bridge) (1) • hence the <u>amplitude</u> of oscillation was kept small (1)		**(3)**

(b)(iii)	• as the viscosity of the fluid increased the fluid would offer greater resistance to movement [accept reverse argument] (1) (1) • a greater resistance to movement would result in a greater energy dissipation		**(2)**

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
	• use of graph to find gradient = k ($= F/x$) **(1)** • use of $T = 1/f$ **(1)** • use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** • $m = 0.05$ (kg) **or** k using 50 g and 2 Hz = 7.9 (N m^{-1}) **or** f using 50 g and k from graph = 2.0 (Hz) **or** T using 50 g and k from graph = 0.50 (s) **(1)** • Comparison and correct conclusion (dependent on MP4) **(1)**	<u>Example of calculation</u> $k = 0.55$ N / 0.07 m $= 7.86$ N m^{-1} $T = ½ = 0.5$ s $0.5 = 2\pi\sqrt{\frac{m}{7.86}}$ $m = 0.050$ kg (0.0498 kg) A smaller mass means a shorter period, so smaller than 0.05 kg would be a higher frequency than 2 Hz, so 50 g is smallest mass.	**5**

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	□ because the (resultant) force is (directly) proportional to displacement from equilibrium position **(1)** □ force is in the opposite direction to displacement **(1)** **or** force is (always) acting towards the equilibrium position		**2**

Q14.

Question Number	Answer		Mark
(a)(i)	Calculation of average time period [accept average time for 10T] Use of $f = \frac{1}{T}$ $f = 1.5$ Hz Example of calculation $T = \frac{t_1 + t_2 + t_3}{30} = \frac{(6.2 + 6.6 + 6.9)\text{s}}{30} = 0.657\,\text{s}$ $f = \frac{1}{0.657\,\text{s}} = 1.52\,\text{Hz}$	(1) (1) (1)	3
(a)(ii)	Force (or acceleration): proportional to displacement from equilibrium position always acting towards the equilibrium position **Or** always in the opposite direction to the displacement [accept rest/centre point for "equilibrium position"] [both marks can be gained from an equation with terms clearly defined including a correct reference to the negative sign]	(1) (1)	2
(b)	There is (large) drag force [accept air resistance for drag] Producing a deceleration **Or** the oscillation is (heavily) damped **Or** energy is transferred/removed from the system [e.g. transferred to the surroundings.] [Do not accept "lost" for "transferred"]	(1) (1)	2
(c)	Resonance Driven at a frequency equal/near the natural frequency of the wings [accept their answer to (a) as a numerical value] [for "driven" accept "forced/made to oscillate"]	(1) (1)	2

Q15.

Question Number	Answer	Mark
	C	1

Q16.

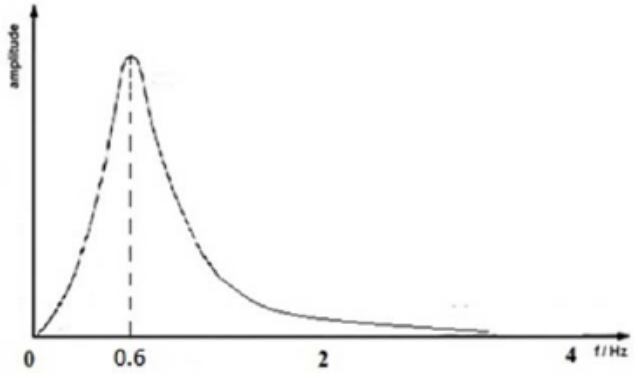
Question Number	Answer	Mark
	C	1

Q17.

Question Number	Answer	Mark
	A	1

Q18.

Question Number	Answer		Mark
(a)(i)	Use of Newton's 2nd law (F = ma) with F = –kx Acceleration/force is in opposite direction to the displacement from the equilibrium position **Or** acceleration/force is (always) towards the equilibrium/undisplaced/rest position Example of calculation: m a = - k x $a = -\frac{k}{m}x$	(1) (1)	2
(a)(ii)	See $a = -\omega^2 x$ Compare with $a = -\frac{k}{m}x$ to give $\omega^2 = \frac{k}{m}$ Substitute for ω using $\omega = \frac{2\pi}{T}$ Example of calculation: $a = -\omega^2 x$ and $a = -\frac{k}{m}x$ $\omega^2 = \frac{k}{m}$ and $\omega = \frac{2\pi}{T}$ $\left(\frac{2\pi}{T}\right)^2 = \frac{k}{m} \quad \therefore T = 2\pi\sqrt{\frac{m}{k}}$	(1) (1) (1)	3
(b)(i)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ Use of $f = \frac{1}{T}$ f = 0.59 Hz Example of calculation: $T = 2\pi\sqrt{\frac{3.5\times10^5\ \text{kg}}{4.8\times16^6\ \text{N m}^{-1}}} = 1.7\ \text{s}$ $f = \frac{1}{T} = \frac{1}{1.7\ \text{s}} = 0.588\ \text{Hz}$	(1) (1) (1)	3

(b)(ii)	Correct shape (1) Single sharp peak (1) With the peak labelled at 0.6 Hz (1)  	3
(b)(iii)	(Max) <u>amplitude</u> of oscillation is reduced (1) as energy is transferred from the mass-spring system (1) and then dissipated (in the surroundings) (1)	3
	Total for question	**14**

Q19.

Question Number	Answer	Mark
(a)	Force (or acceleration): • proportional to displacement from equilibrium/undisplaced/rest position (1) • always acting towards the equilibrium/undisplaced/rest position **Or** always in the opposite direction to the displacement (1)	2
(b)(i)	Acceleration is a maximum at an extreme position (towards X) (1) Acceleration decreases to zero at X (1)	2
(b)(ii)	**Max 3** Total energy remains constant (1) (Elastic) potential energy is transferred to kinetic energy as string moves towards X (1) Kinetic energy is zero at an extreme position and a maximum at X (1) (Elastic) potential energy is a maximum at an extreme position and a minimum at X (1)	3
(c)	Use of $\lambda = 2l$ (1) Use of $v = f\lambda$ (1) $f = 250$ Hz (1) <u>Example of calculation:</u> $\lambda = 2 \times 0.53\ m = 1.06\ m$ $f = v/\lambda = 270\ m\ s^{-1}/1.06\ m = 254.7$ Hz	3
	Total for question	**10**

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Q20.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>
This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th><th>Max linkage mark available</th><th>Max final mark</th></tr>
<tr><td>6</td><td>4</td><td>2</td><td>6</td></tr>
<tr><td>5</td><td>3</td><td>2</td><td>5</td></tr>
<tr><td>4</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>3</td><td>2</td><td>1</td><td>3</td></tr>
<tr><td>2</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td></td></tr>
<tr><td></td><td>
The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>

Indicative content

• 720 Hz is the natural frequency of the bowl
• The generator/hand causes forced/driven oscillations
• When they don't match the natural frequency they are quiet because little/less energy is transferred
• The loudness (at 720 Hz) is because of resonance
</td><td></td><td>6</td></tr>
</table>

	• (Resonance occurs when) the driving frequency is equal/similar to the natural frequency • (When resonance occurs) there is maximum transfer of energy so the amplitude is maximum **Or** (When resonance occurs) there is maximum transfer of energy so the amplitude increases	Do not accept 'resonant frequency' for 'natural frequency'	

Q21.

Question Number	Answer		Mark
	MAX 3		
	Curve A:		
	The system has a maximum amplitude at a particular frequency	(1)	
	This is an example of resonance	(1)	
	Resonance occurs when the forcing frequency is at (or near to) the natural frequency of the system	(1)	
	At resonance there is an efficient/maximum transfer of energy (to the mass-spring system)	(1)	
	MAX 3		
	Curve B:		
	B has a smaller amplitude than A (for a wide range of frequencies)	(1)	
	The modified system has (greater) damping	(1)	
	Energy is being removed from the system	(1)	
	The frequency at which resonance occurs is lower for the damped system	(1)	**4**
	Total for question		**4**

Q22.

Question Number	Answer	Mark
(a)(i)	Resonance / resonating / resonates (1)	1
(a)(ii)	Loudspeaker/driving frequency close or equal to its natural frequency (1) so energy transfer is maximised/large **Or** energy transfer is very efficient (1)	2
(b)	Idea that energy would be transferred (from the glass) to the rubber band (as it deforms) (1) **Or** work is done on the rubber band (by the glass) Some of the (transferred) energy becomes internal energy of rubber band **Or** some of the (transferred) energy is dissipated in the rubber band (1)	2
	Total for Question	5

Q23.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• Pendulum A is $\pi/2$ ahead of pendulum B (1)		1
(ii)	• $T = 1.2$ s from graph (1) • Use of $T = 2\pi\sqrt{(l/g)}$ (1) • $l = 0.36$ m (1)	$T = 3.0$ s / 2.5 oscillations 1.2 s $= 2\pi\sqrt{(l/9.81\ \text{N kg}^{-1})}$ $l = 0.36$ m	3

Q24.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ (1) • $T = 2.24$ (s) (at least 3 sf) (1)	Example of calculation: $T = 2\pi\sqrt{\frac{1.25\ \text{m}}{9.81\ \text{m s}^{-2}}} = 2.24\ \text{s}$	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $\omega = \frac{2\pi}{T}$ (1) • Use of $v = -A\omega \sin \omega t$ (1) • $v = 0.21\ \text{m s}^{-1}$ (ecf from (i)) (1)	Example of calculation: $\omega = \frac{2\pi}{2.24\ \text{s}} = 2.80\ \text{rad s}^{-1}$ $v = -7.5 \times 10^{-2}\text{m} \times 2.80\ \text{s}^{-1} \times 1$ $= 0.210\ \text{m s}^{-1}$	3

Q25.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Use of $T = 2\pi\sqrt{\frac{L}{g}}$ (1) • $L = 0.994$ m (1)	Example of calculation: $L = \frac{(2.00\,\text{s})^2 \times 9.81\,\text{m s}^{-2}}{4\pi^2} = 0.994\,\text{m}$	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	A description that makes reference to the following points: • Record nT (where n is at least 5) **and** divide by n (to find T) (1) • Time oscillations from equilibrium position of bob using a (fiducial) marker **Or** repeats timings for multiple oscillations and calculate mean (1)		2

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	• Using the stopwatch there would be reaction time (1) • The uncertainty in the measurement of the time is larger with the stopwatch than with the data logger. (1) • Timing multiple swings (with stopwatch) reduces %U (1) • Light gates are difficult to use with a pendulum bob. (1)	MP2 dependent on MP1	4

Q26.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Any **TWO** from: • Should have used (a fiducial mark as) a reference point **(1)** • Should have timed from the equilibrium position of the bob **Or** Shouldn't time from the maximum displaced position of the bob **(1)** • Only timed one oscillation **Or** should have times more than one oscillation **(1)** • Should have allowed the pendulum to swing to and fro a few times before starting to time (as the first swing may be different from the others) **(1)**	Accept centre/vertical/undisplaced position for equilibrium position	**2**

Q27.

Question Number	Acceptable Answers	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	3

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	Max linkage mark available
6	4	2
5	3	2
4	3	1
3	2	1
2	2	0
1	1	0
0	0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Indicative content

- The pendulums have the same length, so they have the same time period/frequency
- The first pendulum causes forced oscillations of the second pendulum
- The driving frequency equals the natural frequency
- Resonance occurs, so there is maximum transfer of energy so the amplitude increases until all energy is transferred
- The second pendulum then acts as a driver for the first pendulum
  Or the process repeats with energy transfer from B to A
- When the lengths differ the driving frequency is not the natural frequency of the second pendulum so little energy transfer occurs

Q28.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• No of divisions read from oscilloscope trace • Use of time base setting • Use of $f = 1/T$ • Use of $v = f\lambda$ • $v = 340\ \text{m s}^{-1}$	(1) (1) (1) (1) (1)	MP1: Must be for a recognised part of wave Example of calculation $T = 3 \times 0.20 \times 10^{-3}\ \text{s} = 6.0 \times 10^{-4}\ \text{s}$ $f = \frac{1}{6.0 \times 10^{-4}\ \text{s}} = 1.67 \times 10^{3}\ \text{Hz}$ $v = 1.67 \times 10^{3}\ \text{s}^{-1} \times 0.205\ \text{m} = 342\ \text{m s}^{-1}$	5

Q29.

Question Number	Acceptable answer	Additional guidance	Mark
	D	The only correct answer is **D**: velocity is maximum when displacement is zero, and vice versa, and has positive and negative values since the direction reverses A is not correct because this shows maximum velocity when it should be minimum and vice versa B is not correct because this shows maximum velocity when it should be minimum and vice versa C is not correct because this does not show the change in direction of velocity during an oscillation	1

Q30.

Question Number	Acceptable answers		Additional guidance	Mark
	• Determine period, T • Use of $T = 2\pi\sqrt{(l/g)}$ • Subtracts radius of mass • Length of wire = 10.3 (m)	(1) (1) (1) (1)	Example of calculation $T = 52.2\ \text{s} / 8$ $= 6.53\ \text{s}$ $6.53\ \text{s} = 2\pi\sqrt{(l/9.81\ \text{N kg}^{-1})}$ Length of pendulum to centre of mass = 10.6 m Length of wire = 10.6 m − 0.3 m = 10.3 m	4