SHM MS1

Question Number	Answer	Mark
1 (a)	(Net force) $(\Delta)F=-k(\Delta)x$ (1) Used with $F=ma$ (1)	(2)
(b)	Use of $F=(-)kx$ (1) Correct answer for k OR substitution of expression for k into formula below (1) Use of $\omega^2=k/m$ OR $T=2\pi\sqrt{\frac{m}{k}}$ OR $a_{max}=-\omega^2 A$, with $a_{max}=9.81\ \text{Nkg}^{-1}$ (1) Use of $\omega=2\pi f$ OR $f=1/T$ (1) Correct answer for f (1) Example of calculation: $k=\frac{0.15\,\text{kg}\times 9.81\,\text{N}\,\text{kg}^{-1}}{0.2\,\text{m}}=7.4\,\text{Nm}^{-1}$ $\omega=\sqrt{\frac{7.4\,\text{N}\,\text{m}^{-1}}{0.15\,\text{kg}}}=7.0\left(\text{rad}\,\text{s}^{-1}\right)$ $f=\frac{\omega}{2\pi}=\frac{7\,\text{s}^{-1}}{2\pi}=1.1\,\text{Hz}$	(5)
	Total for question 11	**(7)**

Question Number	Answer		Mark
2(a)	Resonance System driven at / near its natural frequency	(1) (1)	**(2)**
(b)(i)	Any zero velocity point	(1)	**(1)**
(b)(ii)	Any maximum/minimum velocity point	(1)	**(1)**
(c)	Select 70 mm distance from passage/see 35 mm Use of $a = -\omega^2 x$ Use of $v = \omega A$ Correct answer Example of calculation: $\omega = \sqrt{\dfrac{0.89\,\text{ms}^{-1}}{3.5\times10^{-2}\,\text{m}}} = 5.04\,\text{rad s}^{-1}$ $v = \omega A = 5.04\,\text{s}^{-1} \times 3.5\times10^{-2}\,\text{m} = 0.18\,\text{m s}^{-1}$	(1) (1) (1) (1)	**(4)**
(d) **QWC**	The answer must be clear and be organised in a logical sequence The springs/dampers absorb energy (from the bridge) (Because) the springs deform/oscillate with natural frequency of the bridge Hence there is an efficient/maximum transfer of energy Springs/dampers must not return energy to bridge / must dissipate the energy	 (1) (1) (1) (1)	**(max 3)**
	Total for question 18		**(11)**

Question Number	Answer	Mark
3 (a)(i)	Use of $f=1/T$ (1) $f = 8$ Hz (1) Example of calculation $f = \frac{1}{T} = \frac{1}{2 \times 0.0625\,s} = 8$ Hz	**2**
(a)(ii)	At the equilibrium (position) / centre of the oscillation / mid-point (1)	**1**
(a)(iii)	Use of $v_{max}=2\pi fA$ OR $v_{max}=\omega A$ (1) v_{max} = 2.5 ms^{-1} [ecf for (a)(i), see table below] (1) Example of calculation $v = 2\pi f A = 2\pi \times 8 s^{-1} \times 5 \times 10^{-2} m = 2.5 m s^{-1}$	**2**
(b)(i)	Idea that the system is forced / driven into oscillation at / near its natural frequency OR driver / forcing frequency is equal / near to natural frequency (1) Leads to large/max energy transfer OR large/max/increasing amplitude (1)	**2**
(b)(ii)	**Max 2** ♦ Rubber feet (deform and) absorb (vibration) energy (1) ♦ Reference to damping (1) ♦ Idea that energy is removed from system (1) ♦ **Hence** amplitude does not build up (1)	**max 2**
	Total for question 16	**9**

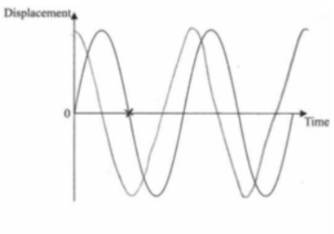
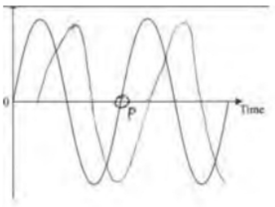
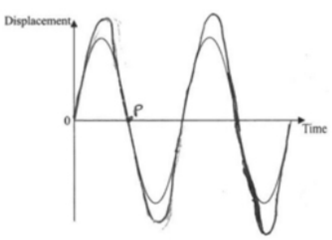
When marking 16(a)(iii) the table below may be helpful:

f/Hz	A/cm	v/ms^{-1}	Marks
8	5	2.5	2
16	5	5	2
8	10	5	1
16	10	10	1

Question Number	Answer		Mark
4(a)	Force (or acceleration): • (directly) proportional to displacement • always acting towards the equilibrium position	(1) (1)	2
(b)	Use of $\omega = 2\pi f$ OR $\omega = 2\pi/T$ Use of $v = A\omega \sin \omega t$ OR $v = A\omega$ $v = 0.35\ \mathrm{m\ s^{-1}}$ [If 5 cm or 10 cm is substituted instead of 2.5 cm then still award second mark] <u>Example of calculation</u> $\omega = 2\pi\ \mathrm{rad} \times \left(\frac{10}{4.5\ \mathrm{s}}\right) = 14.0\ \mathrm{rad\ s^{-1}}$ $v = 2.5 \times 10^{-2}\ \mathrm{m} \times 14.0\ \mathrm{s^{-1}} = 0.35\ \mathrm{m\ s^{-1}}$	(1) (1) (1)	3
(c)	Any **THREE** from • Node at fixed end or antinode at free end • Distance from node to antinode = λ/4 • As (vibrating) length increases, wavelength increases • Reference to v = f λ • The shorter the ruler the higher the frequency	(1) (1) (1) (1) (1)	**Max 3**
	Total for question 15		**8**

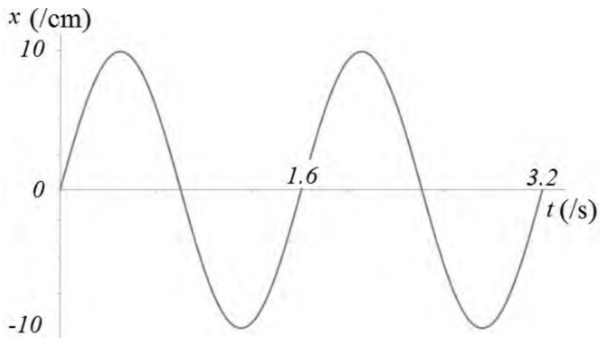
Question Number	Answer		Mark
5 (a)	Acceleration is: • (directly) proportional to displacement from equilibrium position • (always) acting towards the equilibrium position **Or** idea that acceleration is in the opposite direction to displacement [accept undisplaced point/fixed point/central point for equilibrium position] **Or** Force is: • (directly) proportional to displacement from equilibrium position • (always) acting towards the equilibrium position **Or** idea that force is a restoring force e.g. "in the opposite direction" [accept towards 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 $F \propto -x$]	**(1)** **(1)** **(1)** **(1)**	**2**
(b)(i)	Amplitude = 2.3 m [allow ±0.1 m] Time period = 24 hours [allow ±0.5 hour] [24 hours = 86 400 s] Example of calculation Amplitude = (6.1 m – 1.5 m)/2 = 2.3 m Period = (48 hr – 0 hr)/2 = 24 hr	**(1)** **(1)**	**2**
(b)(ii)	Use of $\omega = \frac{2\pi}{T}$ Use of $v = (-)A\omega \sin \omega t$ [$v_{max} = \omega A$] v_{max} = 0.60 m hr^{-1} Example of calculation: $\omega = \frac{2\pi}{T} = \frac{2\pi \text{ rad}}{24 \text{ hr}} = 0.262 \text{ rad hr}^{-1}$ $v_{max} = 0.262 \text{ rad hr}^{-1} \times 2.3 \text{ m} = 0.602 \text{ m hr}^{-1}$ **Or** Attempt to calculate gradient with a max Δt = 12 hours, and max Δx = 6 m Rate of change of depth in range (0.54 – 0.66) m hr^{-1} Rate of change of depth in range (0.57 – 0.63) m hr^{-1} Example of calculation Rate of change of depth = $\frac{(6.5-1.0)}{(11.0-1.5)} = 0.57$	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
(b)(iii)	Graph with correct shape [minus sine curve, at least 30 hours] Same time period as graph given, constant amplitude	**(1)** **(1)**	**2**
	Total for question 13		**9**

Question Number	Answer		Mark
6(a)(i)	Resonance	**(1)**	**1**
(a)(ii)	The vibrations from the engine/road surface/wheels must drive/force the tiger's head (to vibrate) at a frequency equal/close to its natural frequency **Or** Driver/forcing frequency Matches natural frequency	**(1)** **(1)** **(1)** **(1)**	**2**
(b)(i)	Use of $\omega = \frac{2\pi}{T}$ Use of $a_{max} = \omega^2 A$ Amplitude = 2×10^{-2} m <u>Example of calculation</u> $\omega = \frac{2\pi}{0.8\ s} = 7.85\ (rad)s^{-1}$ $A = \frac{1.2\ ms^{-2}}{(7.85\ s^{-1})^2} = 1.95 \times 10^{-2}\ m$	**(1)** **(1)** **(1)**	**3**
(b)(ii)	Correct shape and phase (in antiphase with acceleration) for graph Amplitude (ecf from (b)(i)) **and** a time marked on axes	**(1)** **(1)**	**2**
	Total for question 17		**8**

Question Number	Answer	Mark
7(a)	Pendulum C has same/similar length as pendulum X (1) Therefore C has the same/similar <u>natural</u> frequency as pendulum X **Or** idea that C is driven at its <u>natural</u> frequency (1) (Hence) the energy transfer from X to C is most efficient **Or** There is a maximum transfer of energy from X to C **Or** (1) A correct reference to resonance	**3**
(b)	Any zero displacement point marked on original graph [do not insist on "P"] (1) (Minus) cosine graph drawn with same period as original graph (1) [Ignore amplitude of graph drawn] Examples of graphs:  This candidate has identified "P" (although not used "P") and the cosine graph is well drawn. [2 marks]  This candidate has identified "P" correctly, and has drawn a minus cosine graph. Their graph starts from a time of T/4, which is just about acceptable. [2 marks]  This candidate has identified "P" correctly, but has drawn a sine curve. [1 mark]	**2**
	Total for question 13	**5**

Question Number	Answer		Mark
8(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** $F = k\Delta x$ An extension of the spring causes a force towards the equilibrium position **Or** (resultant force towards the equilibrium position, so) $ma = -k\Delta x$ 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)** **(1)** **(1)**	 **3**
(b)	Use of $a = -\omega^2 x$ Use of $T = \frac{2\pi}{\omega}$ $T = 1.55$ (s) [Credit use of F = k Δx and use of $T = 2\pi\sqrt{\frac{m}{k}}$ for first two marking points] <u>Example of calculation:</u> $\omega = \sqrt{\frac{0.49\,\text{m s}^{-2}}{3.0\times10^{-2}\,\text{m}}} = 4.04\ \text{s}^{-1}$ $T = \frac{2\pi}{4.04\ \text{s}^{-1}} = 1.55\ \text{s}$	**(1)** **(1)** **(1)**	 **3**
(c)(i)	Damped / damping [Do not accept critical/heavy damping]	**(1)**	**1**
(c)(ii)	Forced / driven	**(1)**	**1**
(c)(iii)	Resonance f = 0.65 Hz [accept s^{-1}] [0.625 Hz if show that value is used, 0.64 Hz if unrounded value used] <u>Example of calculation:</u> f = 1/1.55 s = 0.645 Hz [allow 2nd mark if they use either their value from (b) or 1.6 s]	**(1)** **(1)**	 **2**
(d)	(With a smaller mass baby) the natural frequency of oscillation would increase **Or** The natural frequency of the system would increase		

	Or The periodic time of the system would decrease Smaller mass baby would have to kick at a higher frequency (to force system into resonance) [accept larger mass baby would have to kick at a lower frequency]	**(1)** **(1)**	**2**
	Total for question 18		**12**

Question Number	Answer		Mark
9(a)	Acceleration is: • (directly) proportional to displacement (from equilibrium position) • (always) acting towards the equilibrium position **Or** idea that acceleration is in the opposite direction to displacement [for equilibrium position accept: undisplaced point **Or** fixed point **Or** central point] **Or** Force is: • (directly) proportional to displacement (from equilibrium position) • (always) acting towards the equilibrium position **Or** idea that force is a restoring force e.g. "in the opposite direction" [for equilibrium position accept: undisplaced point **Or** fixed point **Or** central point] [An equation with symbols defined correctly is valid for both marks. e.g. $a \propto -x$ **or** $F \propto -x$]	**(1)** **(1)** **(1)** **(1)**	**2**
(b)	Sinusoidal graph [shape not starting point is important] at least 1.5 cycles [symmetrical, but tolerate a small decrease in amplitude] T = 1.6 (s) Amplitude marked as 10 (cm) **Or** A/B marked <u>Example of calculation:</u> $T = \frac{1}{0.625\ \text{s}^{-1}} = 1.60\ \text{(s)}$  	**(1)** **(1)** **(1)** **(1)**	**4**
(c)	Use of $\omega = 2\pi f$ Use of $v_{max} = (\pm)\omega A$ $v = \pm\ 0.39\ \text{m s}^{-1}$ <u>Example of calculation:</u> $\omega = 2\pi \times 0.625 = 3.93\ \text{s}^{-1}$ $v = 3.93\ \text{s}^{-1} \times 0.1\ \text{m} = 0.393\ \text{m s}^{-1}$	**(1)** **(1)** **(1)**	**3**