Question Number	Answer		Mark
1(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**
1(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**
1(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**
1(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**
	Total for question		**9**

<table>
<tr><th>Question Number</th><th>Answer</th><th></th><th>Mark</th></tr>
<tr><td>2(a)</td><td>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 $F \propto -x$]</td><td>(1)
(1)

(1)

(1)</td><td>2</td></tr>
<tr><td>2(b)(i)</td><td>Amplitude = 2.3 m [allow ±0.1 m]
Time period = 24 hours [allow ±0.5 hour]

[24 hours = 86 400 s]

<u>Example of calculation</u>
Amplitude = (6.1 m – 1.5 m)/2 = 2.3 m
Period = (48 hr – 0 hr)/2 = 24 hr</td><td>(1)
(1)</td><td>2</td></tr>
<tr><td>2(b)(ii)</td><td>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}

<u>Example of calculation:</u>
$\omega = \frac{2\pi}{T} = \frac{2\pi \text{ rad}}{24 \text{ hr}} = 0.262 \text{ rad hr}^{-1}$
$v_{max} = 0.262 \text{ rad hr}^{-1} \times 2.3 \text{ m} = 0.602 \text{ m hr}^{-1}$

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}

<u>Example of calculation</u>
Rate of change of depth = $\frac{(6.5-1.0)}{(11.0-1.5)} = 0.57$</td><td>(1)
(1)
(1)

(1)
(1)
(1)</td><td>3</td></tr>
<tr><td>2(b)(iii)</td><td>Graph with correct shape [minus sine curve, at least 30 hours]
Same time period as graph given, constant amplitude</td><td>(1)
(1)</td><td>2</td></tr>
<tr><td></td><td>Total for question</td><td></td><td>9</td></tr>
</table>

Question Number	Answer	Mark
3(a)(i)	Use of $f=1/T$ (1) f = 8 Hz (1) <u>Example of calculation</u> $f = \frac{1}{T} = \frac{1}{2 \times 0.0625\,s} = 8\text{ Hz}$	**2**
3(a)(ii)	At the equilibrium (position) / centre of the oscillation / mid-point (1)	**1**
3(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) <u>Example of calculation</u> $v = 2\pi f\,A = 2\pi \times 8 s^{-1} \times 5 \times 10^{-2}\text{ m} = 2.5\text{ m}s^{-1}$	**2**
3(b)(i)	Idea that the system is forced / driven into oscillation at / near its <u>natural</u> frequency OR driver / forcing frequency is equal / near to <u>natural</u> frequency (1) Leads to large/max energy transfer OR large/max/increasing amplitude (1)	**2**
3(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	**9**

When marking 3(a)(iii) the table below may be helpful:

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

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

Question Number	Answer	Mark
5(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 **(1)** **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) **(1)** [QWC question, so max 2 if equations given with no further explanation]	**3**
5(b)	Use of $a = -\omega^2 x$ **(1)** Use of $T = \dfrac{2\pi}{\omega}$ **(1)** T = 1.55 (s) **(1)** [Credit use of F = k Δx and use of $T = 2\pi\sqrt{\dfrac{m}{k}}$ for first two marking points] <u>Example of calculation:</u> $\omega = \sqrt{\dfrac{0.49\,\text{m}\,\text{s}^{-2}}{3.0\times10^{-2}\,\text{m}}} = 4.04\ \text{s}^{-1}$ $T = \dfrac{2\pi}{4.04\ \text{s}^{-1}} = 1.55\ \text{s}$	**3**
5(c)(i)	Damped / damping [Do not accept critical/heavy damping] **(1)**	**1**
5(c)(ii)	Forced / driven **(1)**	**1**
5(c)(iii)	Resonance **(1)** f = 0.65 Hz [accept s^{-1}] **(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]	**2**
5(d)	(With a smaller mass baby) the natural frequency of oscillation would increase **Or** The natural frequency of the system would increase	

	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**

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