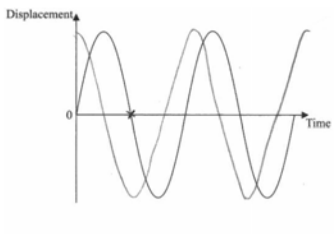
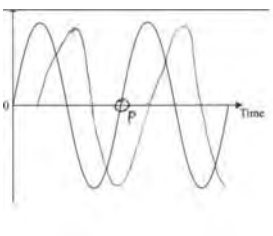
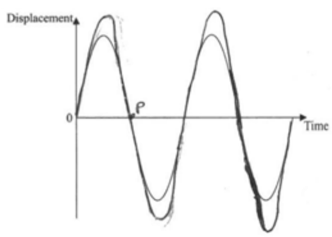
Question Number	Answer	Mark
1(a)(i)	Resonance / resonating / resonates **(1)**	**1**
(a)(ii)	Loudspeaker/driving frequency close or equal to its natural frequency **(1)** so energy transfer is maximised/large **Or** energy transfer is very efficient **(1)**	**2**
1(b)	Idea that energy would be transferred (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**

Question Number	Answer		Mark
2(a)	Pendulum C has same/similar length as pendulum X 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 (Hence) the energy transfer from X to C is most efficient **Or** There is a maximum transfer of energy from X to C **Or** A correct reference to resonance	(1) (1) (1)	3
2(b)	Any zero displacement point marked on original graph [do not insist on "P"] (Minus) cosine graph drawn with same period as original graph [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]	(1) (1)	 2
	Total for question		**5**

Question Number	Answer		Mark
3(a)	Use of $F = \frac{G m_1 m_2}{r^2}$ G = 6.6 × 10^{-11} (N m^2 kg^{-2}) [must see 6.6 × 10^{-11} when rounded to 2 sf] <u>Example of calculation</u> $G = \frac{1.5 \times 10^{-7}\,\text{N} \times (0.23\,\text{m})^2}{160\,\text{kg} \times 0.75\,\text{kg}} = 6.61 \times 10^{-11}\,\text{N}\,\text{m}^2\,\text{kg}^{-2}$	(1) (1)	**2**
3(b)(i)	Read (peak) times from graph for at least 3 cycles T = 6.4 min (±0.2 min) [T = (380 ±12) s] [max 1 mark if correct answer shown without working] <u>Example of calculation</u> $T = \frac{(28.0 - 2.5)\text{min}}{4} = 6.38\text{min}$	(1) (1)	**2**
3(b)(ii)	Air resistance acts on the sphere [accept frictional forces **Or** (viscous) drag for air resistance] Energy is removed from the oscillation/system **Or** the oscillation/system is damped [For mp 2 do not credit ‘energy is lost’ but accept ‘energy is dissipated’; answer must indicate idea of transfer of energy]	(1) (1)	**2**
3(b)(iii)	Evidence of values of at least 3 consecutive peaks read from graph [accept values of 3 points separated by equal time intervals] Attempt to obtain amplitudes, by subtracting 0.75 Calculation of two values of A_{n+1}/A_n with corresponding conclusion **Or** Calculation of two values of difference of ln A_{n+1} and ln A_n with corresponding conclusion **Or** Use peaks of graph to sketch curve Use curve to determine “half-life” [accept other ratio] Calculation of two values of “half-life” with corresponding conclusion <u>Example of calculation</u> A_0 = 1.45-0.75 = 0.7, A_1 = 0.75-0.25 = 0.5, A_2 = 1.1-0.75 = 0.35, A_4 = 0.75 – 0.5 = 0.2	(1) (1) (1) (1) (1) (1)	**3**

	$\frac{A_1}{A_0}=\frac{0.50}{0.70}=0.71$ $\frac{A_2}{A_1}=\frac{0.35}{0.50}=0.70$ $\frac{A_3}{A_2}=\frac{0.25}{0.35}=0.71$	
	Total for question	**9**

Question Number	Answer	Mark
4(a)(i)	Resonance **(1)**	
4(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**
4(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**
4(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**

Question Number	Answer	Mark
***5**	QWC – Work must be clear and organised in a logical manner using technical wording where appropriate **Max 5** • Reference to resonance **(1)** • The sounding box is forced to vibrate (at the frequency of the tuning fork) **(1)** • Tuning fork and sounding box have similar natural frequencies **(1)** • Energy transferred from the tuning fork to the box **(1)** • The sounding box sets a large amount/mass/volume of air into vibration **(1)** • (Hence) the sound (wave) produced (in the air) has a larger amplitude **(1)** • Sounding box dampens the vibration (of the tuning fork) **(1)** • Larger rate of transfer of energy (to the air) means that the vibration persists for a shorter time **(1)**	**5**
	Total for question	**5**

Question Number	Answer	Mark
6(a)	Use of $\omega = \sqrt{\frac{k}{m}}$ and $T = \frac{2\pi}{\omega}$ OR use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** Time period = 0.43 s [allow any value that rounds to 0.4 s] **(1)** <u>Example of calculation</u> $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{120\,\text{N m}^{-1}}{0.55\,\text{kg}}} = 14.8\,\text{rad s}^{-1}$ $T = \frac{2\pi\,\text{rad}}{14.8\,\text{rad s}^{-1}} = 0.425\,\text{s}$	**2**
6(b) (i)	Energy of the system is dissipated or energy is removed from the system (by frictional forces) **(1)** (Hence) the amplitude reduces **(1)**	**2**
6(b) (ii)	Sinusoidal graph with at least 2 cycles **(1)** Decreasing amplitude **(1)** Approximately constant time period **(1)**	**3**
	Total for question	**7**

Question Number	Answer		Mark
7	**M 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**

Question Number	Answer		Mark
8(a)	Use of $F = \frac{G m_1 m_2}{r^2}$ G = 6.6 × 10^{-11} (N m^2 kg^{-2}) [must see 6.6 × 10^{-11} when rounded to 2 sf] <u>Example of calculation</u> $G = \frac{1.5\times10^{-7}\,\text{N}\times(0.23\,\text{m})^2}{160\,\text{kg}\times0.75\,\text{kg}} = 6.61\times10^{-11}\,\text{N}\,\text{m}^2\,\text{kg}^{-2}$	(1) (1)	**2**
8(b)(i)	Read (peak) times from graph for at least 3 cycles T = 6.4 min (±0.2 min) [T = (380 ±12) s] [max 1 mark if correct answer shown without working] <u>Example of calculation</u> $T = \frac{(28.0 - 2.5)\text{min}}{4} = 6.38\text{min}$	(1) (1)	**2**
8(b)(ii)	Air resistance acts on the sphere [accept frictional forces **Or** (viscous) drag for air resistance] Energy is removed from the oscillation/system **Or** the oscillation/system is damped [For mp 2 do not credit ‘energy is lost’ but accept ‘energy is dissipated’; answer must indicate idea of transfer of energy]	(1) (1)	**2**
8(b)(iii)	Evidence of values of at least 3 consecutive peaks read from graph [accept values of 3 points separated by equal time intervals] Attempt to obtain amplitudes, by subtracting 0.75 Calculation of two values of A_{n+1}/A_n with corresponding conclusion **Or** Calculation of two values of difference of ln A_{n+1} and ln A_n with corresponding conclusion **Or** Use peaks of graph to sketch curve Use curve to determine “half-life” [accept other ratio] Calculation of two values of “half-life” with corresponding conclusion <u>Example of calculation</u> A_0 = 1.45-0.75 = 0.7, A_1 = 0.75-0.25 = 0.5, A_2 = 1.1-0.75 = 0.35, A_4 = 0.75 – 0.5 = 0.25	(1) (1) (1) (1) (1) (1)	**3**

	$\frac{A_1}{A_0} = \frac{0.50}{0.70} = 0.71$ $\frac{A_2}{A_1} = \frac{0.35}{0.50} = 0.70$ $\frac{A_3}{A_2} = \frac{0.25}{0.35} = 0.71$	
	Total for question	**9**

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