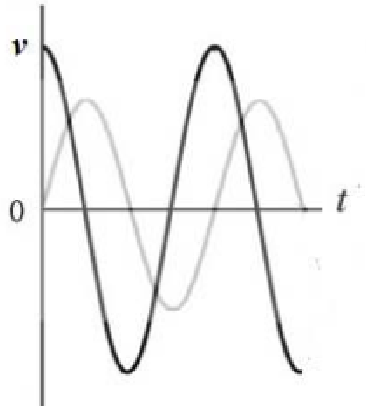
Forced Oscillations and Damping - Mark Scheme

Q1.

Question Number	Answer		Mark
(a)(i)	**Either** (For simple harmonic motion the) acceleration (of the cone) 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** (For simple harmonic motion the resultant) force (on the cone) 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

Question Number	Answer		Mark
(a)(ii)	Use of $v = A\omega(\sin \omega t)$ Use of $\omega = 2\pi f$ $v = 1.6 \text{ m s}^{-1}$ Example of calculation: $v = A\omega \sin\omega t = 2.5\times10^{-3}\text{m}\times 2\pi\times100\text{s}^{-1}\times1 = 1.57\text{ms}^{-1}$	(1) (1) (1)	3
(a)(iii)	 Cosine graph [maximum velocity at t = 0,] Constant amplitude with same period as displacement [dependent mark] [If a minus cosine graph is drawn with same period as displacement and a constant amplitude, then max 1 mark]	(1) (1)	2

*(b)(i)	(QWC Spelling of technical terms must be correct and the answer must be organised in a logical sequence.) This is an example of resonance The unit is driven/forced into oscillation at its natural frequency This results in a maximum energy transfer (from speaker to unit) **Or** this results in a more efficient energy transfer	(1) (1) (1)	3
(b)(ii) **G**	Reference to damping [Description of damping without specific use of the term could gain mark] Damping linked to removal of energy from the unit	(1) (1)	2
(c)	Tweeter has to move at high frequency/acceleration So the tweeter requires a small mass **Or** Woofer has to set a large volume of air into oscillation Because it produces low frequency sounds [Bald statement that tweeter has high frequency or woofer has low frequency for 1 mark maximum]	(1) (1) (1) (1)	2
	Total for question		**14**

Q2.

Question Number	Answer		Mark
(a)(i)	resultant force (of magnitude) kx acts on car, where x is displacement from equilibrium position (Appling Newton's 2nd Law) $ma = -kx$ Identifies $\omega^2 = \frac{k}{m}$ (from $a = -\omega^2 x$) Use of $\omega = 2\pi f$ leading to $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$	(1) (1) (1) (1)	4
(a)(ii)	Use of mg = (–)kΔx k = 30.3 (kN m^{-1}) <u>Example of calculation</u> $k = \frac{mg}{\Delta x} = \frac{85.0\,\text{kg} \times 9.81\,\text{N kg}^{-1}}{27.5 \times 10^{-3}\,\text{m}} = 3.03 \times 10^4\,\text{Nm}^{-1}$	(1) (1)	2
(a)(iii)	Use of $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ f = 0.79 Hz <u>Example of calculation</u> $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi} \times \sqrt{\frac{3.03 \times 10^4\,\text{Nm}^{-1}}{(1130+85)\text{kg}}} = 0.7948\,\text{Hz}$	(1) (1)	2

*(b)(i)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Idea that damping is the transfer of energy (from the oscillating system) **(1)** (Damping is desirable because) it reduces <u>amplitude</u> of vibration **(1)** So that oscillations die away quickly **Or** so that it prevents transfer of energy to oscillation of car body **(1)**	**3**
(b)(ii)	Cosine variation (constant time period; frequency of 2 graphs should be approximately equal) **(1)** Amplitude decreasing with time (dependent upon mp1) **(1)**	**2**
	Total for Question	**13**

Q3.

Question Number	Answer	Mark
(a)(i)	Resonance is when a system is driven/forced (into oscillation) at its natural frequency **(1)** (Accept close to its natural frequency) This results in: A maximum energy transfer **(1)** **Or** a maximum/increasing amplitude **Or** a maximum efficiency of energy transfer	**2**
(a)(ii)	the wavelength is larger (hence the frequency is smaller) **(1)**	**1**
(b)(i)	(Damping is) the removal/dissipation of energy from an oscillation **(1)** (Hence) there is a decrease in the amplitude **(1)**	**2**
(b)(ii)	As the gel changes size/shape it absorbs energy **(1)** The gel does not return to its original size/shape **(1)** So the energy is not returned (to the drum) **Or** the energy is dissipated (in the gel) **(1)** [dependent upon mp1 or mp2]	**3**
	Total for Question	**8**

Q4.

Question Number	Answer		Mark
(a)	Use of $F = k\Delta x$ (ignore reference to any minus signs) $k = 1560\ (\text{N m}^{-1})$ Example of calculation: $k = \frac{mg}{\Delta x} = \frac{35\text{kg} \times 9.81\text{N kg}^{-1}}{0.22\text{m}} = 1560\text{N m}^{-1}$	(1) (1)	2
(b)(i)	Use of $F = m\omega^2 x$ and $F = (-)k\Delta x$ Use of $\omega = 2\pi f$ $f = 1.1$ Hz [apply ecf for responses that use a value of k that would round to the 'show that' value] [Candidates who quote $T = 2\pi\sqrt{\frac{m}{k}}$, then use $f = \frac{1}{T}$ and get the correct answer score full marks. If their answer incorrect, could score mp2 only] Example of calculation: $m\omega^2 x = k\Delta x$ $\therefore \omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{1560\text{ N m}^{-1}}{35\text{kg}}} = 6.68\text{ s}^{-1}$ $f = \frac{\omega}{2\pi} = \frac{6.68\text{s}^{-1}}{2\pi} = 1.06\text{Hz}$	(1) (1) (1)	3
(b)(ii)	Use of $v_{max} = \omega A$ **Or** Use of $v_{max} = 2\pi f A$ $v_{max} = 1.4\text{ m s}^{-1}$ ecf their value of ω or f [if A = 0.22 then max 1 for calculation] Max velocity is at the equilibrium position [accept centre/mid-point of oscillation] Example of calculation: $v_{max} = \omega A = 6.68\text{s}^{-1} \times 0.21\text{m} = 1.40\text{ m s}^{-1}$	(1) (1) (1)	3

(c)(i)	Resonance [accept resonating/resonates] (By using her knees) she is forcing herself into oscillation at a frequency close or equal to the natural frequency of the system So the transfer of energy becomes very efficient **Or** there is maximum/large energy transfer	(1) (1) (1)	3

* (c)(ii)	QWC – Work must be clear and organised in a logical manner using technical wording where appropriate For shm there must be a (resultant) force/ acceleration proportional to displacement from the equilibrium position **(1)** [Accept undisplaced point/fixed point/central point for equilibrium position] When she loses contact with the trampoline the (only) force is the weight **(1)** **Or** When she loses contact with the trampoline the acceleration is *g* Weight/g is constant (so not shm) **(1)** **Alternative scheme for those who consider the direction of the force/acceleration rather than its magnitude** For shm there must be a force/acceleration that is always directed towards the equilibrium position **(1)** When she loses contact with the trampoline the (only) force is the weight **Or** When she loses contact with the trampoline the acceleration is *g* **(1)** Weight/*g* is always directed downwards (so not shm) **(1)**		3
	Total for question		**14**

Q5.

Question Number	Answer	Amplification	Mark
	C	The only correct answer is **C** A is not correct because it will deform very little B is not correct because the deformation will not be permanent D is not correct because it will deform very little	**1**

Q6.

Question Number	Answer	Mark
	B forced oscillation	**1**
	Incorrect Answers: A – the table is being forced to oscillate by the phone C – resonance only happens at a particular frequency, the natural frequency of the table. Any oscillation of the table makes the sound louder. D – it is the sound waves set up in the air that makes the sound louder and these are not standing waves	

Q7.

	Answer		Mark
(a)	Idea that bridge is being forced/driven into oscillation	(1)	
	At its natural frequency (accept "close to" for "at")	(1)	
	Resulting in a maximum transfer of energy to the bridge **Or** Appropriate reference to resonance	(1)	**3**
(b)	See $\lambda = 2l$ Use of $v = f\lambda$ $v = 100\ \mathrm{m\ s^{-1}}$	(1) (1) (1)	**3**
	<u>Example of calculation</u> $\lambda = 2l = 2\times 91 = 182$ m $v = f\lambda = 0.55\ \mathrm{Hz} \times 182\ \mathrm{m} = 100.1\ \mathrm{m\,s^{-1}}$		
	Total for Question		**6**

Q8.

Question Number	Answer	Mark
	The only correct answer is B ***A*** *is not correct because maximum velocity increases as Aincreases* ***C*** *is not correct because maximum velocity increases as Aincreases* ***D*** *is not correct because maximum velocity increases as A increases*	**(1)**

Q9.

Question Number	Answer	Mark
	The only correct answer is B ***A*** *is not correct because elastic deformations return energy to the oscillation* ***C*** *is not correct because stiff materials require large stresses to deform* ***D*** *is not correct because strong materials withstand large stresses without breaking*	**1**

Q10.

Question Number	Answer	Mark
	The only correct answer is B ***A*** *is incorrect, as elastic deformation returns energy to the building* ***C*** *is incorrect, as stiffness is unrelated to energy dissipation.* ***D*** *is incorrect, as strength is unrelated to energy dissipation.*	(1)