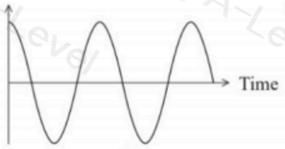
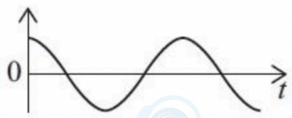
10	**The only correct answer is A**  B is not correct because the phase difference between the oscillations is incorrect C is not correct because the phase difference between the oscillations is incorrect D is not correct because the phase difference between the oscillations is incorrect	1

6	**B is the correct answer** A is not correct, as this describes an elastic material C is not correct, as this describes a strong material D is not correct, as this describes a stiff material	(1)

4	**C is the only correct answer (mass will oscillate at the frequency of the vibration generator.)** A is not the correct answer, as the amplitude is only a maximum for resonance B is not the correct answer, as the mass is forced to oscillate at the vibrator frequency D is not the correct answer, as the energy transfer is only a maximum for resonance	1

9	**C is the only correct answer** 	1

10	**B is the correct answer,** as the gradient of the velocity-time graph gives the displacement time graph	(1)

6	**B is the only correct answer**, as $T = 2\pi\sqrt{\frac{m}{k}}$ and $f = \frac{1}{T}$	1

2	**The only correct answer is B (The frequency of oscillation of the mass is a maximum.)** A is not correct because at resonance the amplitude of oscillation is a maximum C is not correct because at resonance mass is being driven at its natural frequency D is not correct because at resonance the transfer of energy is a maximum	1

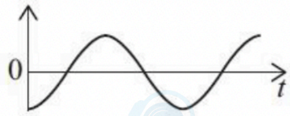
7	**B is the only correct answer,** as $v_{max} = \omega A$	(1)

9	**D is the only correct answer**, as force is exactly out of phase with the displacement	1

3	**A is the only correct answer (4*E*)** B is not the correct answer, as $E_k = \frac{1}{2}mv^2$ and $v_{max} = \omega A$ C is not the correct answer, as $E_k = \frac{1}{2}mv^2$ and $v_{max} = \omega A$ D is not the correct answer, as $E_k = \frac{1}{2}mv^2$ and $v_{max} = \omega A$	1

8	**D is the correct answer (amplitude of oscillation decreased more slowly)** A is not correct because the frequency has not decreased B is not correct because the period has not increased C is not correct because initially the pendulum has more energy	1

2	**A is the only correct answer**, as ductile materials deform plastically	1

10	**B is the only correct answer** 	1

4	**D is the only correct answer**, as $a \propto -x$	1

4	**B is the only correct answer** A is not the correct answer, as acceleration is always towards the equilibrium point C is not the correct answer, as acceleration is always towards the equilibrium point D is not the correct answer, as this would increase the energy of oscillation	(1)

Question Number	Answer		Mark
20(a)	There is a (resultant) acceleration / force that is proportional to the displacement from the equilibrium position	(1)	
	and (always) acting towards the equilibrium position	(1)	2
	(An equation with symbols defined correctly is a valid response for both marks For equilibrium position accept: undisplaced point / position or fixed point / position or central point / position)		

(b) When the wind blows at a certain speed, the building oscillates with a frequency of 0.17 Hz.

(i) Explain why the damper system should be designed to oscillate at this frequency.

(2)

20(b)(ii)	Use of $\rho = \frac{m}{V}$	**(1)**	
	Use of $T = 1/f$	**(1)**	
	Use of $T = 2\pi\sqrt{\frac{m}{k}}$	**(1)**	
	$k = 3.1 \times 10^5\ \text{N m}^{-1}$	**(1)**	**4**
	Example of calculation $m = (5.20\ \text{m})^2 \times 0.90\ \text{m} \times 11300\ \text{kg m}^{-3} = 2.75 \times 10^5\ \text{kg}$ $T = \frac{1}{f} = \frac{1}{0.17\ \text{Hz}} = 5.88\ \text{s}$ $k = \frac{4\pi^2 m}{T^2} = \frac{4\pi^2 \times 2.75 \times 10^5\ \text{kg}}{(5.88\ \text{s})^2} = 3.14 \times 10^5\ \text{N m}^{-1}$		

20(b)(iii)	**MAX 2**		
	The motion of the box is (strongly) damped	**(1)**	
	Amplitude at resonance is small	**(1)**	
	Lead box has a large mass/inertia	**(1)**	
	A large force is needed to set box into motion	**(1)**	**2**

20(c)	Work is done (by roller) as oil is forced through the holes	**(1)**	
	So energy is transferred from the building (and not returned) **Or** energy is transferred to the surroundings (and not returned) [Accept "dissipated" for "transferred to surroundings"]	**(1)**	**2**

Question Number	Answer		Mark
15(a)	Conversion of beats minute^{-1} to Hz [Accept calculation of T]	(1)	
	Use of $\omega = 2\pi f$	(1)	
	Use of $v = -A\omega \sin \omega t$ with $\sin \omega t = 1$	(1)	
	A = 1.5 (mm) [Allow max displacement = 2A]	(1)	4
	Example of calculation $f = \frac{142}{60\text{ s}} = 2.37\text{ Hz}$ $\omega = 2\pi \times 2.37\text{ s}^{-1} = 14.9\text{ rad s}^{-1}$ $A = \frac{22.0 \times 10^{-3}\text{ m s}^{-1}}{14.9\text{ s}^{-1}} = 1.48 \times 10^{-3}\text{ m} = 1.48\text{ mm}$		
15(b)	For an object to move with simple harmonic motion there must be an acceleration/(resultant) force that is proportional to the displacement from the equilibrium position	(1)	
	and (always) acting towards the equilibrium position	(1)	2
	(For equilibrium position accept: undisplaced point/position or fixed point/position or central point/position) [MP2 Accept acceleration/force is in the opposite direction to the displacement] [An attempt to use the equation can only score if all terms are defined and the minus sign explained]		
	Total for question 15		**6**

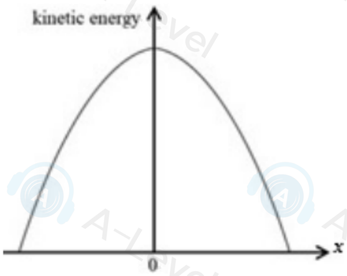
Question Number	Answer		Mark
19(a)(i)	Use of $F = mg$	(1)	
	Use of $\Delta F = k\Delta x$	(1)	
	$k = 45.3\ (\text{N m}^{-1})$	(1)	3
	[If g = 10 N kg^{-1} is used, then max 2 marks]		
	Example of calculation $k = \frac{0.55\text{ kg} \times 9.81\text{ N kg}^{-1}}{11.9 \times 10^{-2}\text{ m}} = 45.3\text{ N m}^{-1}$		

19(a)(ii)	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)	
	$f = 2.1$ Hz (ecf value of k from (a)(i))	(1)	4
	Example of calculation $m = \frac{45.3 \text{ N m}^{-1} \times 5.8 \times 10^{-2} \text{ m}}{9.81 \text{ N kg}^{-1}} = 0.268 \text{ kg}$ $T = 2\pi\sqrt{\frac{0.268 \text{ kg}}{45.3 \text{ N m}^{-1}}} = 0.483 \text{ s}$ $f = \frac{1}{0.483 \text{ s}} = 2.07 \text{ Hz}$		

19(b)	The driving/forcing frequency (of the animal) equals the natural frequency (of the spring balance) **Or** The bag/spring/balance/scale(s) is forced to oscillate at its natural frequency [Accept 'driven at its natural frequency'; accept 'close to its natural frequency']	**(1)**	
	There is a large transfer of energy (to the bag) **Or** There is maximum energy transfer (to the bag) **Or** Resonance occurs [Accept 'maximum efficiency of energy transfer']	**(1)**	**2**

Question Number	Answer		Mark
17(a)	**MAX 2**		
	The graph is a straight line through the origin with a negative gradient	(1)	
	(Hence) the acceleration is proportional to the displacement (from the equilibrium position)	(1)	
	(And) the acceleration is in the opposite direction to the displacement	(1)	2

17(b)(i)	Value of a and corresponding value of x read from graph Use of $a = (-)\omega^2 x$ to determine ω **Or** gradient used to determine ω Use of $v = \omega A \sin \omega t$ with $\sin \omega t = 1$ Use of $E_k = \frac{1}{2}mv^2$ $E_k = 3.5 \times 10^{-3}$ J **ALTERNATIVE SOLUTION:** Value of a corresponding to value of x_{max} read from graph Use of $F = ma$ Use of $E_{el} = \frac{1}{2}Fx$ States $E_k = E_{e;}$ $E_k = 3.5 \times 10^{-3}$ J <u>Example of calculation</u> Gradient $= \frac{(0.7-(-0.7))\ \text{m s}^{-2}}{(-0.04-0.04)\ \text{m}} = -17.5\ \text{s}^{-2}$ $\omega = \sqrt{17.5\ \text{s}^2} = 4.18\ \text{rad s}^{-1}$ $v_{max} = 4.18\ \text{rad s}^{-1} \times 0.04\ \text{m} \times 1 = 0.167\ \text{m s}^{-1}$ $E_k = \frac{1}{2} \times 0.25\ \text{kg} \times (0.167\ \text{m s}^{-1})^2 = 3.486\ \times 10^{-3}$ J	(1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	5

17(b)(ii)	Parabolic curve with only positive value of K.E. Graph has a single maximum. [This must be $x = 0$] <u>Example of graph</u> 	(1) (1)	2
	Total for question 17		**9**

Question Number	Answer		Mark
20(a)	There is a (resultant) force that is proportional to the displacement from the equilibrium position and (always) acting towards the equilibrium position (Allow references to acceleration. An equation with symbols defined correctly is a valid response for both marks. For equilibrium position accept: undisplaced point/position or fixed point/position or central point/position.)	 (1) (1)	2

20(b)	**EITHER** Use of $F = mg$ **(1)** Use of $\Delta F = (-)k\Delta x$ **(1)** Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** Use of $\omega = \frac{2\pi}{T}$ [Allow use of $\omega = \sqrt{\frac{k}{m}}$ for MP3 and MP4] **(1)** Use of $v = \omega x_0 \sin \omega t$ **(1)** $v_{max} = 0.34 \text{ m s}^{-1}$ **(1)** **OR** Use of $F = mg$ **(1)** Use of $\Delta F = (-)k\Delta x$ **(1)** Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ **(1)** Use of $E_k = \frac{1}{2}mv^2$ **(1)** Use of energy conservation **(1)** $v_{max} = 0.34 \text{ m s}^{-1}$ **(1)** [If $T = 2\pi\sqrt{\frac{\ell}{g}}$ is used, then correct answer scores 6 marks. If answer is incorrect, then credit **may** be obtained for MP1, MP2, MP4, MP5] <u>Example of calculation</u> $F = 0.150 \text{ kg} \times 9.81 \text{ N kg}^{-1} = 1.47 \text{ N}$ $k = \frac{1.47 \text{ N}}{7.5 \times 10^{-2} \text{ m}} = 19.6 \text{ N m}^{-1}$ $T = 2\pi\sqrt{\frac{0.150 \text{ kg}}{19.6 \text{ N m}^{-1}}} = 0.549 \text{ s}$ $\omega = \frac{2\pi \text{ rad}}{0.549 \text{ s}} = 11.4 \text{ rad s}^{-1}$ $v_{max} = 11.4 \text{ rad s}^{-1} \times 3.0 \times 10^{-2} \text{ m} = 0.343 \text{ m s}^{-1}$		6

20(c)	Energy is transferred out of the oscillating system **Or** energy is dissipated (to surroundings) Because work is done by/against resistive forces (Allow MAX 1 for reference to damping)	(1) (1)	2
	Total for question 20		**10**