1)

Question			Expected Answers	Marks	Additional guidance
4	a		The resultant force is zero (WTTE) Forces are weight and force from the spring (allow tension)	B1 B1	For the first mark allow - sum of forces is zero, - upward force = downward force, - forces cancel each other BUT do not allow forces are balanced Allow force of gravity for weight
	b	i	acceleration is (directly) proportional to displacement and is directed in the opposite direction to the displacement. (WTTE)	M1 A1	allow $a=-(2\pi f)^2 x$, provided a and x are identified and –ve sign must be explained. Do not allow "acceleration is prop to negative displacement for second mark. Allow always towards the equilibrium position
		ii	$x= a\cos 2\pi ft \Rightarrow 2\pi f = 7.85$ (expressed in any form) $f = (7.85/2\pi) = 1.25$ (1.249Hz)	**M1** A1	Do not allow use of Fig 4.2 to show T= 0.8s and hence f=1.25 Hz. This scores 0.
		iii	correct substⁿ in $V_{max} = (2\pi f)A \Rightarrow V_{max} = 2\pi x 1.25 x 0.012$ V_{max} = **0.094** ms^{-1}	C1 A1	Many will forget to change 12 mm into 0.012m and have v = 94 ms^{-1} this scores 1 mark.
	c		roughly **sinusoidal** graph of correct period ie **0.8s** 90° out of phase with displacement graph (i.e. starts at origin with -ve initial gradient) maximum velocity correctly shown as 0.094 {allow ecf from (iii)}	B1 B1 B1	
			Total	**11**	

2)

Question			Answer	Marks	Guidance
	(a)	(i)	Straight line through the origin Negative gradient and symmetrical about (0,0) by eye.	M1 A1	
		(ii)	Linking gradient to $[2\pi f]^2$. Frequency = $\frac{\sqrt{\text{gradient}}}{2\pi}$	C1 A1	**Allow:** use of a single data point used in $a = (-)[2\pi f]^2 x$ **Note** frequency must be the subject of this equation
	(b)	(i)	$A = \frac{v_{max}}{2\pi f} = \frac{0.09}{2\pi \times 8.0}$ $A = 1.8 \times 10^{-3}$ (m)	C1 A1	**Allow:** values for T in range 0.125 to 0.13 s
		(ii)	$a_{max} = (2\pi f)^2 A$ $a_{max} = (2\pi \times 8.0)^2 \times 1.8 \times 10^{-3}$ $a_{max} = 4.5$ (ms^{-2})	C1 A1	Possible ecf from b(i) **Allow:** Tangent drawn on graph at any $v = 0$ point (C1) calculation of gradient (A1)
	(c)		Curve with same frequency /period max velocities decreasing at **three** successive **positive** peaks	B1 B1	**Allow**: ½ small square error on $v = 0$ points
	(d)		Axes labelled and graph showing correct bell shaped curve (amplitude increases then decreases) Maximum/largest amplitude or energy at f=8 Hz / natural frequency When driving/oscillator's frequency is equal to natural frequency / 8 Hz **resonance** occurs (AW).	B1 B1 B1	**Allow** this mark if curves are drawn asymptotically (to 8 Hz) May be scored on diagram or in text '**resonance**'/ '**resonant**' to be spelled correctly for this mark to be scored.
			Total	**13**	

3)

Question			Answer	Marks	Guidance
3	(a)	(i)	C and F	B1	
		(ii)	G	B1	
		(iii)	$5\pi/4$ (= 1.25 π) or 3.93 (rad)	B1	
	(b)	(i)	Correct shape graph (by eye) Through the points (-5,0) (0,50) and (5,0)	B1 B1	**Note :** Max KE = 80 – 30 = 50 (mJ)
		(ii)	½ (0.45)v_{max}^2 = 50 x 10^{-3} v_{max} = 0.47 (m s^{-1})	A1	**Allow** ECF if max value on y axis from b(i) is used. If max KE = 80 mJ then v_{max} = 0.596 = 0.60 (m s^{-1})
		(iii)	$v_{max} = \frac{2\pi A}{T}$ $T = \frac{2\pi(5.0\times10^{-2})}{0.47}$ $T = 0.67\,(s)$	C1 A1	**Allow** C1 mark for correct frequency =1.5 (Hz) ECF from b(ii) Using v_{max} = 0.60 leads to T = 0.52 (s) and using v_{max} = 0.596 leads to T = 0.53 (s)
			Total	**8**	

4)

	a		(Fig. 2.1 shows) *a* and *x* are in opposite directions (Fig. 2.2 shows that magnitude of) *a* is proportional to *x* because graph is a straight line through the origin	**B1** **B1**	**Allow** *a* is towards the equilibrium position Reason must be given
	b		gradient = $\omega^2 = \frac{40}{50\times10^{-3}} = 800$ $T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{800}} = 0.22$ (s)	**C1** **A1**	**Allow** : use of equation and one point from graph **Allow:** Max 1 mark for T = 7 (s) (not converting mm to m)
	c	**i**	$[k] = \left[\frac{ma}{x}\right] = \frac{\text{kg}\times\text{m s}^{-2}}{\text{m}}$ $[k]$ = kg s^{-2}	**C1** **A1**	**Allow:** C1 mark for any subject
		ii	$\frac{k}{m}$ is gradient $\frac{k}{m} = 800$ (s^{-2})	 **A1**	**Possible ECF from (b)** Ignore sign
	d		• The period / frequency of the oscillations would remain the same • Successive **amplitude(s)** would decrease in magnitude • energy is dissipated as heat / thermal energy / work is done against friction (AW)	**B1** **B1** **B1**	**amplitude** must be spelled correctly to score this mark **Allow:** 1 mark for bald statement that motion would be 'damped harmonic ' or suitable sketch.

	e	i	• **C** continues to move in a straight line as the tube rotates (by N1st Law) stretching the spring. • Spring exerts a force on **C** which provides the centripetal acceleration (by Newton's 2nd law) to rotate **C** (in a circle of appropriate radius).	**B1** **B1**	No credit for bald statement of laws. They must be applied to the problem.
		ii	Any **four** from • Measure natural length of spring **OR** Measure mass of **C** with balance/scale(s). • Rotate at constant speed and video apparatus and ruler • Measure *R* from video • Find period *T* from video and speed *v* from $2\pi R/T$ • Measure extension from video **OR** calculate extension, *x*, from *R* and natural length • Use spring constant and $F = kx$ / Hooke's law **OR** substitute *M*, *v* *R* into $F = Mv^2/R$ to find force *F*	**B1 x 4**	
		iii1	*FR* / Nm	**B1**	Must have appropriate unit (ignore any prefix)
		iii2	$m = FR / v^2$ [any subject] mass is gradient of graph	**C1** **A1**	**Possible ecf from (iii)1**
			Total	**19**	

5)

Question	Expected Answers	Marks	Additional guidance
(a)(i)	displacement is the distance (of the body) from an equilibrium position. amplitude is the maximum displacement.	B1 B1	Allow mean/rest/central/mid point Not original, fixed point This mark can only be gained if the word maximum/greatest/largest is spelled correctly. Allow distance
(a)(ii)	frequency is the number of oscillations/cycles per unit time/second angular frequency is product of 2π x frequency OR 2π/period.	B1 B1	Do not allow "swings" Allow $2\pi f$
(b)(i) 1	amplitude = (18 – 13)/2 = **2.5** m	B1	
(b)(i) 2	frequency = 1/(12.5 x 3600) = (1/45000) = **2.2(2) x 10^{-5}** Hz	C1 A1	Accept any valid subⁿ of time for 1st mark Accept 0.08 h^{-1} OR 1.3×10^{-3} min^{-1} if unit is seen to replace Hz.
(b)(ii)	correct use of $v_{max} = 2\pi fA$ e.g. $2\pi \times 2.22 \times 10^{-5} \times 2.5$ = **3.5 x 10^{-4}** m s^{-1} (3.46 or 3.49)	C1 A1	Allow ecf from (b)(i)1 and 2 for full marks: if A=5 is used $v_{max} = 6.98 \times10^{-4}$ (6.9 to 7) if A=18 is used $v_{max} = 2.5\times10^{-3}$
(b)(iii)	correct use of A(cos $2\pi ft$): e.g. $2.5 \cos [2\pi \times 2.22 \times 10^{-5} t]$ (= $2.5 \cos (1.39 \times 10^{-4} xt)$ $d = 15.5 + 2.5 \cos [2\pi \times 2.22 \times 10^{-5} t]$ OR $15.5 + 2.5 \cos (1.39\times10^{-4} x t)$	C1 A1	Allow $2.5 \cos[2\pi t/45000]$ Accept A(sin $2\pi ft$) throughout Allow ecf from (b)(i) and (b)(ii)
	Total	**11**	

6)

(a)	(i)	amplitude = 0.4(0) (m) **and** period = 5.(0) (s)	B1	**Note**: Both values are required. **Allow** 1 sf values
	(ii)	$\omega = (2\pi f) = 2\pi / T$ $\omega = 2\pi / 5.0 = (2\pi \times 0.2)$ $\omega = 1.3$ (rad s^{-1})	 C1 A1	Possible ecf from a(i) for period Mark is for correct substitution
(b)	(i)	V clearly marked at any point where graph crosses time axis	B1	
	(ii)	A clearly marked at any point where graph crosses time axis	B1	
	(iii)	P clearly marked at any point where graph crosses time axis	B1	
(c)	(i)	Selecting from data sheet $a = -(2\pi f)^2 x$ $a_{max} = (-)(2\pi \times 2.4 \times 10^3)^2 \times 1.8 \times 10^{-3}$ $a_{max} = 4.1 \times 10^5$ (m s^{-2})	C1 C1 A1	**Allow**: $a = (-)\omega^2 x$ **Note**: Ignore sign of a **Allow**: 2 marks for 4.1×10^n, $n \neq 5$ [POT error]
	(ii)	Work done = mean force x distance moved For ¼ oscillation distance moved = 1.8 mm, Work done = $0.25 \times 1.8 \times 10^{-3}$ ($= 4.5 \times 10^{-4}$ J) Time taken Δt = ¼ T = ¼ $(1/2.4 \times 10^3) = 1.04 \times 10^{-4}$ Power = work done / Δt = $0.25 \times 1.8 \times 10^{-3} / 1.04 \times 10^{-4}$ = **4.3 W** Power = 4.3 (W)	 C1 C1 A1	**Allow:** other correct values of distance moved and compatible time taken. Eg 7.2 (mm) and 4.17×10^{-4} (s) for 1 complete oscillation
		Total	**12**	

7)

(a)		Obtain a set of readings for: mass m, time period AND calculate frequency using $f = 1/T$. Plot graphs of f against $1/m$ AND f against $1/\sqrt{m}$ The graph which is a straight line through the origin provides the correct relationship Reference to one method of improving reliability eg counting more than 5 oscillations to find T or f taking repeat measurements of T or f (and average values) time oscillations from equilibrium position	B1 B1 B1 B1	**Not** number of oscillations in a set time **Allow:** product method using two or more points (B1) Select the relation which gives a constant product (B1) **Allow:** plot ln f against ln m (B1) gradient= -1 then $f \propto 1/m$ **or** gradient= -0.5 then $f \propto 1/\sqrt{m}$ (B1)
(b)	**(i)**	$v_{max} = 2\pi f A = 2\pi\left(\frac{1}{1.2}\right) \times 36 \times 10^{-3}$ $v_{max} = \frac{3\pi}{50} \quad (= 0.188)$ $KE_{max} = \frac{1}{2} \times 0.4 \times \left(\frac{3\pi}{50}\right)^2$ $KE_{max} = 7.1 \times 10^{-3}$ (J)	C1 C1 A1	**Note:** mark is for substitution
	(ii)	$a_{max} = (2\pi f)^2 A = \left[2\pi\left(\frac{1}{1.2}\right)\right]^2 \times 36 \times 10^{-3}$ $a_{max} = 0.99$ (ms^{-2})	C1 A1	**Note:** mark is for correct substitution

8)

Question	Expected Answers	Marks	Additional guidance
(a)	Acceleration is (directly) proportional to the displacement/distance (from the equilibrium position/central pt) Acceleration is always directed towards the equilibrium position/central point.	B1 B1	Allow "fixed point" or "point" Allow acc. is in opposite direction to displacement (WTTE) If formula is used: allow a $\propto$ -x for 1st mark and 2nd mark if x is stated as displacement.
(b) (i)	Curve symmetrical about energy axis with maximum at 18 zero at +0.04 and – 0.04	B1 B1	Ignore points where graphs cross Give bod if not labelled **K** but correct
(b) (ii)	Horizontal straight line passing 18	B1	Give bod if not labelled **T** but correct
(c) (i)	0.04 m	B1	
(c) (ii)	$\frac{1}{2}m(v_{max})^2 = 0.018$ $v_{max} = \sqrt{(2x0.018/0.12)} =$ **0.55** ms^{-1} (0.548)	C1 A1	Many will use 18 instead of 0.018. This results in 17.3 and scores 1 mark. Allow ecf for cand's value of max KE. Do not allow 0.54 for second mark.
(c) (iii)	correct use of $v_{max} = 2\pi fA$ $f = (0.55/0.04x2\pi) =$ **2.2** (or 2.19 or 2.18)Hz	C1 A1	Allow ecf for cand's values from (c)(i) and/or (c) (ii). E.g for 17.3 f = 68.8 Hz. This scores 2 marks e.c.f. Do not allow 2.1
(d)	Award first mark for stating the **'driver'** of the oscillations and the second mark for stating what is **'driven'** i.e. oscillating useful applications: e.g. Cooking: **micro waves** cause **water molecules** to resonate Woodwind: **reed** causes **air column** to resonate Brass: **lips** cause **air column** to resonate MRI: **radio waves** (in a magnetic field) cause **nuclei/proton** to resonate Radios: **radio waves** cause **electrons/current** to resonate Person on swing: **intermittent pushes** cause **swing** to resonate problem: Bridges: **wind/walkers** causes **bridge** to resonate Vehicles: **engine vibrations** cause **panels/mirrors** to resonate Earthquakes: **ground vibrating** causes **buildings** to resonate	B1 B1 B1 B1	No marks to be awarded for a bare statement of the example e.g MRI. Please allow any other valid examples.
	Total	14	

9)

Q2	Expected Answers	Marks	Additional guidance
(a)(i)	Force/acceleration is proportional to displacement (from equilibrium position) (Resultant force) force/acceleration is (always) towards equilibrium position (WTTE, e.g. allow fixed point).	B1 B1	**Allow** force/acceleration is in opposite direction to the displacement. **Allow** acc $\propto x$, provided x is identified as the displacement for 1st mark. 2nd mark only scored if –ve sign used and explained.
(a)(ii)	True; False False; False	B2	-1 for each error stop at zero Assume ✓ means true and X means false Do not credit blank spaces
(b)	***Measurements***: angle measured with protractor stated or shown on the diagram stop-watch/ms timer/data-logger to measure time stated or shown on the diagram ***Conclusion:*** compare periods for different angles stated/implied OR plot period against angle ***major difficulty:*** angle of swing decreases during the timing of the swing ***solution:*** e.g. measure time for ¼, ½ or 1 swing accurately (using electronic timer/datalogger) OR use data logger with motion sensor to record many swings and analyse how the period changes over time OR video the motion with onscreen timer and analyse	 B1 B1 B1 M1 A1	**Allow** ruler used to measure initial and subsequent displacement/amplitude if explained. **Allow** table of results with correct column headings i.e. at least angle and period Do not allow 'time is short so measure nT and divide by n to reduce (%) error'.(WTTE)
	Total	**9**	

10)

(a)		acceleration proportional to displacement (from the equilibrium position)	B1	**displacement** must be spelled correctly to score the mark. **Allow:** acceleration proportional to distance from equilibrium position with equilibrium spelled correctly for first B1
		and is always acting towards the equilibrium position / the mid-point of the motion (AW)	B1	**Allow:** 'acceleration is in the opposite direction to displacement' for the second B1 mark **Use tick or cross on Scoris**
(b)	(i)	$v_{max} = 2\pi f A \qquad f = 1/0.08 = 12.5$ $v_{max} = 2\pi\left(\frac{1}{0.080}\right) \times 1.2 \times 10^{-3} \left(= 2\pi \times 12.5 \times 1.2 \times 10^{-3}\right)$	C1	If A = 0.6 mm used $v_{max} = 2\pi\left(\frac{1}{0.080}\right) \times 0.6 \times 10^{-3}$ (✓) $v_{max} = 4.7 \times 10^{-2}$ (m s^{-1}) (✓)
		$v_{max} = 9.4 \times 10^{-2}$ (m s^{-1})	A1	**Note:** Answer to 3 sf is 9.42 x 10^{-2} (m s^{-1}) **Allow:** 1 mark for 94(.2) (m s^{-1}) not converting mm to m
	(ii)	This occurs at the highest point (top) of the oscillations When acceleration of plate equals/exceeds free fall acceleration /g/ 9.81	B1 B1	
		$g = (2\pi f)^2 A_0$ hence $A_0 = \frac{9.81}{\left(2\pi \times \frac{1}{0.080}\right)^2}$	C1	**Allow:** equation with any subject for this mark
		A_0 = 1.6 x 10^{-3} (m)	A1	**Note:** Answer to 3 sf is 1.59 x 10^{-3} (m)
(c)	(i)	Resonance Driving / drum frequency matches natural frequency (of casing) (AW)	B1 B1	
	(ii)	Graph with peak amplitude **less than** original peak amplitude Similar shape curve with peak at the **same** or **lower** frequency than given curve Curve is lower than given curve at all frequencies	M0 A1 A1	Must see this before subsequent marks can be scored.
		Total	**12**	

11)

(a)		Is in the opposite direction to the displacement Increases as the speed of the object decreases	B1 B1	If more than 2 ticks are given mark all and deduct 1 mark for each error
(b)	**(i)**	$f = \frac{1}{T} = \frac{1}{1.2}$ $f = 0.83$ (Hz)	B1	**Allow:** the fraction 5/6 only
	(ii)	$v_{max} = (2\pi f)\ A$ $0.08 = (2\pi \times 0.83)A$ $A = \frac{0.08}{(2\pi \times 0.83)} = 0.015$ (m)	C1 A1	Possible **ecf** from **(b)(i)** **Note:** Mark is for substitution; any subject Answer is 0.0153 (m) to 3 sf
	(iii)	$a_{max} = (2\pi f)^2 A$ $a_{max} = (2\pi \times 0.83)^2 \times 0.015$ $a_{max} = 0.42$ (ms^{-2})	C1 A1	Possible **ecf** from **(b)(i)** and **(ii)** **Note:** Mark is for substitution **Ignore sign** Expect to see 0.41 if 2 sf values are used **Allow:** tangent used at $v = 0$ (M1) gradient of tangent calculated in range 0.37 to 0.44 (m s^{-2}) to 2sf (A1). Accept gradient of tangent =0.4 (m s^{-2})
(c)	**(i)**	Graph(s) tending to single peak with axes labelled in words or appropriate symbols Peak labelled as natural / resonant frequency (of system) or f_o • Resonance occurs when the driving frequency matches natural / resonant frequency (of system) • the amplitude of vibrations / energy (transferred) is then a maximum (AW)	B1 B1 B1 B1	Can be scored even if horizontal axis is not correctly labelled
	(ii)	A valid example of resonance Explanation to include • what does the driving and what is being driven • that this occurs at specific (driver) frequency	B1 B1	**Allow:** Mirror in car, Washing machine, Child on swing, microwave (oven), radio (tuning), Structures (in wind etc) MRI **Not** musical instruments
		Total	**13**	

12)

(a)	(i)	T = 2.4 (s) f = 1/T = 1/2.4 = 0.42 (Hz)	A1	No marks for T = 3 (s) leading to f = 0.33 (Hz).
	(ii)	$v_{max} = 2\pi fA$ $v_{max} = 2\pi \times \frac{1}{2.4} \times 50 \times 10^{-3}$ $v_{max} = 0.13 \quad (m\,s^{-1})$	 C1 A1	**Allow:** Tangent drawn on graph at any x = 0 point (C1) calculation of gradient to give value in range 0.12 to 0.14 ($m\,s^{-1}$) (A1) Mark is for substitution. Possible ecf from a(i). Answer to 3 sf = 0.131 ($m\,s^{-1}$). Expect v_{max} = 0.10 ($m\,s^{-1}$) if answer in (i) f = 0.33 Hz (T=3).
(b)	(i)	frequency is the same / not changed since (in SHM) it is independent of amplitude / (starting) displacement (AW)	B1	**Allow:** ...since length of pendulum is unchanged
	(ii)	(maximum velocity) is reduced because amplitude / (starting) displacement is reduced (AW) (Max) KE is reduced to one quarter / 4 times smaller	B1 B1	**Allow:** (Max) KE is smaller since amplitude/ (starting) displacement is smaller **Allow:** (Max) KE is smaller because GPE is smaller
(c)	(i)	Straight line through origin means acceleration ∝ displacement Negative gradient means acceleration and displacement are in opposite directions / acceleration directed is towards the midpoint/equilibrium point (AW)	B1 B1	**Allow:** Straight line through origin means a ∝ x **Allow:** 1 mark for straight line through origin and negative gradient means $a \propto -x$ (hence SHM)
	(ii)	(Magnitude) Gradient = $\omega^2 = 5/0.004 = (2\pi f)^2$ $f = 5.6 \quad (Hz)$	C1 A1	C1 mark is for substitution of gradient for ω^2 or $(2\pi f)^2$ Answer to 3 sf = 5.63 (Hz) **Allow:** 1 mark for f = 0.178 (Hz) not converting mm to m
		Total	10	