1	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 <u>with protractor</u> stated or shown on the diagram <u>stop-watch/ms timer/data-logger</u> 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**	

Question	Expected Answers	Marks	Additional guidance
2(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)	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) (	Horizontal straight line passing 18	B1	Give bod if not labelled **T** but correct
(c)	0.04 m	B1	
(c) (	$\frac{1}{2}m(v_{max})^2 = 0.018$ $v_{max} = \sqrt{(2x0.018/0.12)} =$ **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) (i	correct use of $v_{max} = 2\pi fA$ f = (0.55/0.04x2π) = **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	

Question			Answer	Marks	Guidance
3	(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

Question			Answer	Marks	Guidance
	(c)		**Reference to** : kinetic energy (of masses and spring), gravitational potential energy (of mass and spring), elastic (potential) energy / strain energy of spring KE: zero (at lowest point), increasing to max at equilibrium point, decreasing to zero (at highest point) GPE: increases (as masses rise from lowest to highest point) (clearly worded ora)(AW) strain / elastic energy: decreases (as masses rise from lowest to highest point) (clearly worded ora) (AW)	B1 B1 B1 B1	**Note:** mark to be awarded only if **all** 3 forms are quoted ✎ **Note: potential** must be spelled correctly throughout to score this mark
			Total	**13**	

Question			Answer	Marks	Guidance
4	(a)	(i)	amplitude = 0.4(0) (m) **and** period = 5.(0) (s)	B1	**Note**: Both values are required. **Allow** 1 sf values
		(ii)	$\omega = (2\pi f) = 2\pi / \tau$ $\omega = 2\pi / 5.0 = (2\pi \times 0.2)$ $\omega = 1.3$ (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 $\Delta t = ¼ T = ¼ (1/2.4 \times 10^3) = 1.04 \times 10^{-4}$ Power = work done / $\Delta t = 0.25 \times 1.8 \times 10^{-3} / 1.04 \times 10^{-4}$ = **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**	