Question			Answer	Marks	Guidance
1	(a)	(i)	Straight line <u>through</u> the origin Negative gradient and symmetrical about (0,0) by eye.	M1 A1	
		(ii)	Linking gradient to $[2\pi f]^2$. Frequency= $\dfrac{\sqrt{\text{gradient}}}{2\pi}$	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)	$A = \dfrac{v_{\text{max}}}{2\pi f} = \dfrac{0.09}{2\pi \times 8.0}$ $A = 1.8 \times 10^{-3}$ (m)	C1 A1	**Allow:** values for T in range 0.125 to 0.13 s
		(ii)	$a_{\text{max}} = (2\pi f)^2 A$ $a_{\text{max}} = (2\pi \times 8.0)^2 \times 1.8 \times 10^{-3}$ $a_{\text{max}} = 4.5 \quad (\text{m s}^{-2})$	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) <u>Maximum/largest</u> amplitude or energy at f=8 Hz / natural frequency When <u>driving/oscillator's frequency</u> 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**	

Question			Answer	Marks	Guidance
2	(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)	$v_{max} = 2\pi fA$ $v_{max} = 2\pi \times \frac{1}{2.4} \times 50 \times 10^{-3}$ $v_{max} = 0.13$ (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)	<u>Straight line through origin</u> means acceleration ∝ displacement <u>Negative gradient</u> means acceleration and displacement are in opposite directions / acceleration directed is towards the midpoint/equilibrium point (AW)	B1 B1	**Allow:** <u>Straight line through origin</u> means a ∝ x **Allow:** 1 mark for <u>straight line through origin</u> and <u>negative gradient</u> means $a \propto -x$ (hence SHM)
		(ii)	(Magnitude) Gradient = $\omega^2 = 5/0.004 = (2\pi f)^2$ $f = 5.6$ (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	

Question			Answer	Marks	Guidance
3	(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)	$f = \frac{1}{T} = \frac{1}{1.2}$ $f = 0.83 \quad (\text{Hz})$	B1	**Allow:** the fraction 5/6 only
		(ii)	$v_{max} = (2\pi f)\ A$ $0.08 = (2\pi \times 0.83)A$ $A = \frac{0.08}{(2\pi \times 0.83)} = 0.015 \quad (\text{m})$	C1 A1	Possible **ecf** from **(b)(i)** **Note:** Mark is for substitution; any subject Answer is 0.0153 (m) to 3 sf
		(iii)	$a_{max} = (2\pi f)^2 A$ $a_{max} = (2\pi \times 0.83)^2 \times 0.015$ $a_{max} = 0.42 \quad (\text{m s}^{-2})$	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 <u>natural / resonant</u> frequency (of system) or f_o • Resonance occurs when the <u>driving frequency</u> matches <u>natural / resonant</u> frequency (of system) • the <u>amplitude</u> of vibrations / energy (transferred) is then a <u>maximum</u> (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**	

Question			Answer	Marks	Guidance
4	(a)		acceleration proportional to displacement (from the equilibrium position) and is always acting towards the equilibrium position / the mid-point of the motion (AW)	B1 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 **Allow:** 'acceleration is in the opposite direction to displacement' for the second B1 mark **Use tick or cross on Scoris**
	(b)	(i)	$v_{\max} = 2\pi fA$ $\quad f = 1/0.08 = 12.5$ $v_{\max} = 2\pi\left(\frac{1}{0.080}\right)\times 1.2\times 10^{-3}\left(= 2\pi\times 12.5\times 1.2\times 10^{-3}\right)$ $v_{\max} = 9.4\times 10^{-2}$ (m s^{-1})	C1 A1	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}) (✓) **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 $g = (2\pi f)^2 A_0$ hence $A_0 = \frac{9.81}{\left(2\pi\times\frac{1}{0.080}\right)^2}$ A_0 = 1.6 x 10^{-3} (m)	B1 B1 C1 A1	 **Allow:** equation with any subject for this mark **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**	