

Total 41 marks.

Each marking point ends with ✓ and is worth one mark. Words in « » are not needed for the mark. A correct numerical answer with no working is awarded full marks unless the Notes say otherwise. ECF = error carried forward: award the mark if the candidate used their own wrong earlier answer correctly. Do not penalize errors in units or significant figures unless the Notes say so.

Question 1: A glider between two springs

Part	Answers	Notes	Total
1(a)	the acceleration/restoring force is proportional to the displacement «from the equilibrium position» ✓ the acceleration/restoring force is directed towards the equilibrium position / is opposite to the displacement ✓	Do not award marks for stating the defining equation $a = -\omega^2 x$ alone. Award [1 max] for the equation with a and x defined.	2
1(b)	the graph is a straight line through the origin, so a is proportional to x ✓ the gradient is negative, so a is in the opposite direction to x / towards the equilibrium position ✓	Do not accept “the graph is linear” without reference to the origin for MP1.	2
1(c)	gradient = $-5.4/0.060 = -90$ «s ⁻² » ✓ $\omega^2 = 90$, so $\omega = 9.5$ «rad s ⁻¹ » ✓ $T = 2\pi/\omega = 0.66$ «s» ✓	Award [1 max] for $T = 2\pi/90 = 0.070$ s (gradient taken as ω). Accept any correct pair of values read from the line. Do not accept the use of $\omega^2 = k/m$ with an assumed k.	3
1(d)	amplitude $x_0 = 0.060$ «m» «read from the end of the line» ✓ $v_{\max} = \omega x_0 = 9.5 \times 0.060 = 0.57$ «m s ⁻¹ » ✓	Allow ECF from (c).	2

Question 2: A simple pendulum

Part	Answers	Notes	Total
2(a)	the kinetic energy is zero at each end / the energy repeats twice in each oscillation, every 0.80 «s» ✓ $T = 2 \times 0.80 = 1.6$ «s» ✓	Award [1 max] for 0.80 s.	2
2(b)	$l = gT^2/4\pi^2$ «from $T = 2\pi\sqrt{l/g}$ » ✓ $l = 9.8 \times 1.6^2/4\pi^2 = 0.64$ «m» ✓	Allow ECF from (a). (0.80 s gives 0.16 m.)	2
2(c)	$\frac{1}{2} \times 0.20 \times v^2 = 4.5 \times 10^{-3}$ ✓ $v = 0.21$ «m s ⁻¹ » ✓	Award [1 max] if 4.5 is used in joules ($v = 6.7$ m s ⁻¹).	2

2(d)	the restoring force is $mg \sin \theta$ and the mass being accelerated is m , so $a = -g \sin \theta \approx -\langle g/l \rangle x$: m cancels ✓ so $\omega^2 = g/l$ and $T = 2\pi\sqrt{l/g}$, which does not contain m ✓	Award [0] for " $T = 2\pi\sqrt{l/g}$ " has no m in it" with no reasoning.	2
2(e)	(i) the period does not change ✓ (ii) the maximum kinetic energy doubles «it equals the loss of gravitational potential energy mgh , and h is the same» ✓		2

Question 3: (HL) The needle of a sewing machine

Part	Answers	Notes	Total
3(a)	$x_0 = 0.012 \text{ «m»}$ ✓ $f = \omega/2\pi = 30/2\pi = 4.8 \text{ «Hz»}$ ✓	Do not accept $\omega = 30 + 5\pi/6$.	2
3(b)	$x = 0.012 \sin(5\pi/6) = \langle + \rangle 0.0060 \text{ «m»}$ ✓ $v = \omega x_0 \cos(5\pi/6)$ is negative, so the needle is moving downwards «towards the centre» ✓	For MP2 the direction must be justified with the sign of v or $\cos(5\pi/6)$. Do not allow "towards the equilibrium position" alone.	2
3(c)	$v = 0.36 \cos(30t + 5\pi/6) \text{ «m s}^{-1}\text{»}$ ✓ $a = -10.8 \sin(30t + 5\pi/6) \text{ «m s}^{-2}\text{»}$ ✓	Accept $a = -900x$.	2
3(d)	phase = $30 \times 0.050 + 5\pi/6 = 4.12 \text{ «rad»}$; $v = 0.36 \cos 4.12 = -0.20 \text{ «m s}^{-1}\text{»}$ ✓ $a = -10.8 \sin 4.12 = \langle + \rangle 8.9 \text{ «m s}^{-2}\text{»}$ ✓	Allow ECF from (c). Award [1 max] if the calculator is in degrees.	2
3(e)	$\Delta\phi = 5\pi/6 - \pi/3 = \pi/2 \text{ «rad»}$ ✓ $\Delta t = \Delta\phi/\omega = (\pi/2)/30 = 0.052 \text{ «s»}$ / a quarter of the period ✓		2

Question 4: (HL) A mass on a vertical spring

Part	Answers	Notes	Total
4(a)	$e = mg/k = 0.25 \times 9.8/16 = 0.15 \text{ «m»}$ ✓		1
4(b)	$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{(0.25/16)}$ ✓ $T = 0.785 \text{ «s»}$ ✓	The answer must be given to at least 3 s.f., or the substitution must be shown.	2
4(c)	$\omega = \sqrt{k/m} = 8.0 \text{ «rad s}^{-1}\text{»}$ OR $\omega = 2\pi/T$ ✓ $E_T = \frac{1}{2}m\omega^2 x_0^2 = \frac{1}{2} \times 0.25 \times 8.0^2 \times 0.050^2 = 0.020 \text{ «J»}$ ✓	Accept $\frac{1}{2}kx_0^2 = \frac{1}{2} \times 16 \times 0.050^2 = 0.020 \text{ J}$.	2

4(d)	elastic potential energy «of the spring» decreases and gravitational potential energy increases all the way up ✓ kinetic energy increases to a maximum at the equilibrium position and then decreases to zero at the highest point ✓	Award [1 max] if gravitational potential energy is not mentioned.	2
4(e)	$\frac{1}{2}m\omega^2x^2$ is the energy of the oscillation, measured from the equilibrium position, where the spring is already stretched / the extension of the spring at the lowest point is $e + x_0$, not x_0 ✓ extension = $0.153 + 0.050 = 0.203$ «m» ✓ $E = \frac{1}{2}kx^2 = \frac{1}{2} \times 16 \times 0.203^2 = 0.33$ «J» ✓	Allow ECF from (a).	3
4(f)	$T/2 = 0.39$ «s» ✓	Allow ECF from (b). Award [0] for 0.79 s.	1
4(g)	$v_{\max} = \omega x_0 = 8.0 \times 0.050 = 0.40$ «m s ⁻¹ » ✓	Accept from $\frac{1}{2}mv^2 = 0.020$ J.	1