

Mark Scheme

Q1.

Question Number	Answer	Mark
	C	1

Q2.

Question Number	Answer	Mark
	A	1

Q3.

Question Number	Answer	Mark
	D	1

Q4.

Question Number	Answer	Mark
	B – 0.40 Hz	1
	Incorrect Answers: Correct method: $f = 24 \div 60 \text{ s} = 0.40 \text{ Hz}$ A – uses $1 \text{ minute} \div 24$ C – uses $60 \text{ s} \div 24$ D – uses $24 \div 1 \text{ minute}$	

Q5.

Question Number	Answer	Mark
	C	1

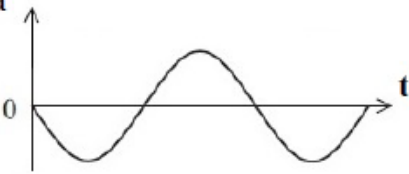
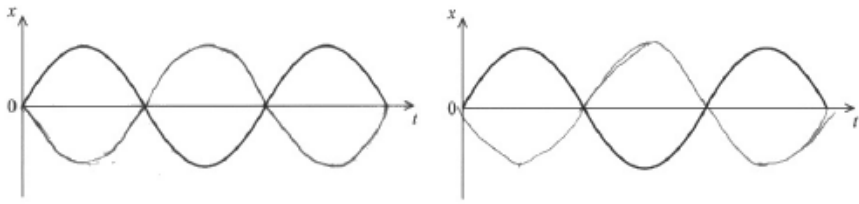
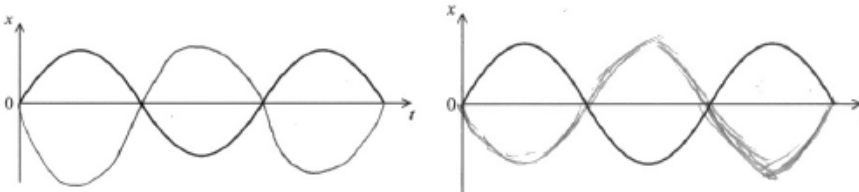
Q6.

Question Number	Answer	Mark
	C	1

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D because velocity is equal to the gradient of the displacement-time graph A is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as proportional to -1 times the displacement B is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as -1 times the gradient C is not correct because velocity is equal to the gradient of the displacement-time graph, but here velocity is shown as proportional to the displacement		1

Q8.

Question Number	Answer	Mark
(b)(i)	Acceleration is: - proportional to displacement from equilibrium position (1) (always) acting towards the equilibrium position Or idea that acceleration is in the opposite direction to displacement (1) Or Force is: - proportional to displacement from equilibrium position (1) (always) acting towards the equilibrium position Or idea that force is a restoring force e.g. "in the opposite direction" (1) [accept undisplaced point/fixed point/central point for equilibrium position] [An equation with symbols defined correctly is a valid response for both marks. e.g. $a \propto -x$ or $F \propto -x$]	2
(b)(ii)	Minus sine curve with constant amplitude (1) a  Examples of acceptable graphs:  Examples of unacceptable graphs: 	1

Question Number	Acceptable Answer	Additional Guidance	Mark
	Max 4 from 2 out of 3 pairs - The student should let the pendulum swing back and to before starting the stopwatch. (1) - The first swing may be affected by the student pushing the bob as they release it (1) - The student should use a (fiducial) marker at O (1) - Easier to determine when it passes O (1) - Time more oscillations (1) - A longer time reduces (%) uncertainty (in T) (1)	For each pair, the second marking point is dependent on the first marking point MP4: Accept the pendulum travelling fastest when it passes O	4

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	- new spring constant = 11 N m^{-1} (1) - Use of $T = 2\pi\sqrt{\frac{m}{k}}$ (1) - Use of $f = 1/T$ (1) $f = 1.5 \text{ Hz}$ (1)	<u>Example of calculation:</u> $k = 22/2 = 11 \text{ N m}^{-1}$ $T = 2\pi\sqrt{\frac{0.12\text{kg}}{11\text{N m}^{-1}}} = 0.66\text{s}$ $f = 1/0.66 \text{ s} = 1.5 \text{ Hz}$	4

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	- discards value for l_3 (1) $l_m = 85.7$ (cm) (1)	MP2: answer to 1 d.p. only <u>Example of calculation</u> $l_m = \frac{85.5 + 86.0 + 85.5}{3} = 85.7 \text{ cm}$	2
(ii)	- Use of $T = 2\pi\sqrt{\frac{\ell}{g}}$ (1) $T = 1.86$ s (1)	ECF from (i) MP2: accept $T = 1.9$ s <u>Example of calculation</u> $T = 2\pi\sqrt{\frac{\ell}{g}}$ $= 2\pi \times \sqrt{\frac{0.857 \text{ m}}{9.81 \text{ m s}^{-2}}} = 1.86 \text{ s}$	2

Q12.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	Pendulum A is $\pi/2$ ahead of pendulum B (1)		1
(ii)	$T = 1.2$ s from graph (1) - Use of $T = 2\pi\sqrt{l/g}$ (1) $l = 0.36$ m (1)	$T = 3.0 \text{ s} / 2.5 \text{ oscillations}$ $1.2 \text{ s} = 2\pi\sqrt{l/9.81 \text{ N kg}^{-1}}$ $l = 0.36 \text{ m}$	3

Q13.

Question Number	Answer	Mark
(i)	Identification of weight and force from cone, F_c, as the two forces acting on the sand (1) Weight – $F_c = m\omega^2 x$ (1) So as x increases, F_c decreases, sand loses contact with cone when $F_c = 0$ (1)	3
(ii)	Resultant force equated to weight Or acceleration equated to g (1) Use of $\omega = 2\pi f$ (1) $f = 32 \text{ Hz}$ (1) <u>Example of calculation:</u> $mg = m\omega^2 x_0$ $\omega = \sqrt{\frac{g}{x_0}} = \sqrt{\frac{9.81 \text{ m s}^{-2}}{0.25 \times 10^{-3} \text{ m}}} = 198 \text{ rad s}^{-1}$ $f = \frac{\omega}{2\pi} = \frac{198}{2\pi} = 31.5 \text{ Hz}$	3

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	- Use of $T = 2\pi\sqrt{\frac{L}{g}}$ (1) $L = 0.994 \text{ m}$ (1)	<u>Example of calculation:</u> $L = \frac{(2.00 \text{ s})^2 \times 9.81 \text{ m s}^{-2}}{4\pi^2} = 0.994 \text{ m}$	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	A description that makes reference to the following points: - Record nT (where n is at least 5) and divide by n (to find T) (1) - Time oscillations from equilibrium position of bob using a (fiducial) marker Or repeats timings for multiple oscillations and calculate mean (1)		2

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	- Using the stopwatch there would be reaction time (1) - The uncertainty in the measurement of the time is larger with the stopwatch than with the data logger. (1) - Timing multiple swings (with stopwatch) reduces %U (1) - Light gates are difficult to use with a pendulum bob. (1)	MP2 dependent on MP1	4

Q15.

Question Number	Answer	Mark
(a)	Use of $F = \frac{Gm_1m_2}{r^2}$ (1) $G = 6.6 \times 10^{-11} \text{ (N m}^2 \text{ kg}^{-2}\text{)}$ [must see 6.6×10^{-11} when rounded to 2 sf] (1) <u>Example of calculation</u> $G = \frac{1.5 \times 10^{-7} \text{ N} \times (0.23 \text{ m})^2}{160 \text{ kg} \times 0.75 \text{ kg}} = 6.61 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	2
(b)(i)	Read (peak) times from graph for at least 3 cycles (1) $T = 6.4 \text{ min } (\pm 0.2 \text{ min})$ [T = (380 ± 12) s] (1) [max 1 mark if correct answer shown without working] <u>Example of calculation</u> $T = \frac{(28.0 - 2.5) \text{ min}}{4} = 6.38 \text{ min}$	2
(b)(ii)	Air resistance acts on the sphere [accept frictional forces Or (viscous) drag for air resistance] (1) Energy is removed from the oscillation/system (1) Or the oscillation/system is damped [For mp 2 do not credit 'energy is lost' but accept 'energy is dissipated'; answer must indicate idea of transfer of energy]	2
(b)(iii)	Evidence of values of at least 3 consecutive peaks read from graph [accept values of 3 points separated by equal time intervals] (1) Attempt to obtain amplitudes, by subtracting 0.75 (1) Calculation of two values of A_{n+1}/A_n with corresponding conclusion Or Calculation of two values of difference of $\ln A_{n+1}$ and $\ln A_n$ with corresponding conclusion (1) Or Use peaks of graph to sketch curve (1) Use curve to determine "half-life" [accept other ratio] (1) Calculation of two values of "half-life" with corresponding conclusion (1) <u>Example of calculation</u> $A_0 = 1.45 - 0.75 = 0.7, A_1 = 0.75 - 0.25 = 0.5, A_2 = 1.1 - 0.75 = 0.35, A_4 = 0.75 - 0.5 = 0.25$	3

	$\frac{A_1}{A_0} = \frac{0.50}{0.70} = 0.71$ $\frac{A_2}{A_1} = \frac{0.35}{0.50} = 0.70$ $\frac{A_3}{A_2} = \frac{0.25}{0.35} = 0.71$	
Total for question		9

Q16.

Question Number	Answer		Mark
(a)(i)	Calculation of average time period [accept average time for 10T] Use of $f = \frac{1}{T}$ $f = 1.5 \text{ Hz}$ Example of calculation $T = \frac{t_1 + t_2 + t_3}{30} = \frac{(6.2 + 6.6 + 6.9)\text{s}}{30} = 0.657 \text{ s}$ $f = \frac{1}{0.657 \text{ s}} = 1.52 \text{ Hz}$	(1) (1) (1)	3
(a)(ii)	Force (or acceleration): proportional to displacement from equilibrium position always acting towards the equilibrium position Or always in the opposite direction to the displacement [accept rest/centre point for “equilibrium position”] [both marks can be gained from an equation with terms clearly defined including a correct reference to the negative sign]	(1) (1)	2
(b)	There is (large) drag force [accept air resistance for drag] Producing a deceleration Or the oscillation is (heavily) damped Or energy is transferred/removed from the system [e.g. transferred to the surroundings.] [Do not accept “lost” for “transferred”]	(1) (1)	2
(c)	Resonance Driven at a frequency equal/near the natural frequency of the wings [accept their answer to (a) as a numerical value] [for “driven” accept “forced/made to oscillate”]	(1) (1)	2

Q17.

Question Number	Answer	Mark
(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) (Hooke's Law:) for a spring, force is proportional to extension Or $F = k \Delta x$ (1) An extension of the spring causes a force towards the equilibrium position (1) Or (resultant force towards the equilibrium position, so) $ma = -k \Delta x$ Condition for shm is restoring force [acceleration] is proportional to displacement (from equilibrium position) (1) [QWC question, so max 2 if equations given with no further explanation]	3
(b)	Use of $a = -\omega^2 x$ (1) Use of $T = \frac{2\pi}{\omega}$ (1) $T = 1.55$ (s) (1) [Credit use of $F = k \Delta x$ and use of $T = 2\pi \sqrt{\frac{m}{k}}$ for first two marking points] <u>Example of calculation:</u> $\omega = \sqrt{\frac{0.49 \text{ m s}^{-2}}{3.0 \times 10^{-2} \text{ m}}} = 4.04 \text{ s}^{-1}$ $T = \frac{2\pi}{4.04 \text{ s}^{-1}} = 1.55 \text{ s}$	3
(c)(i)	Damped / damping [Do not accept critical/heavy damping] (1)	1
(c)(ii)	Forced / driven (1)	1
(c)(iii)	Resonance (1) $f = 0.65 \text{ Hz}$ [accept s^{-1}] (1) [0.625 Hz if show that value is used, 0.64 Hz if unrounded value used] <u>Example of calculation:</u> $f = 1/1.55 \text{ s} = 0.645 \text{ Hz}$ [allow 2nd mark if they use either their value from (b) or 1.6 s]	2
(d)	(With a smaller mass baby) the natural frequency of oscillation would increase Or The natural frequency of the system would increase	

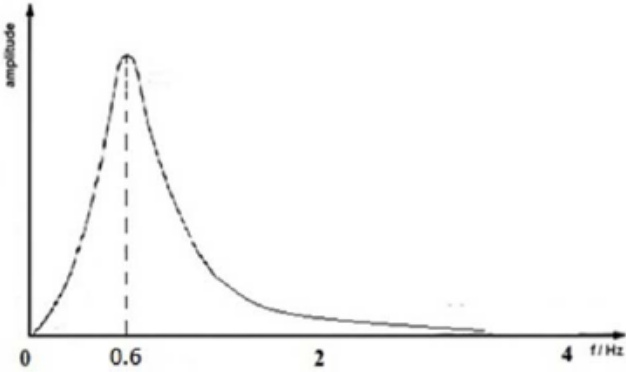
	Or The periodic time of the system would decrease	(1)	
	Smaller mass baby would have to kick at a higher frequency (to force system into resonance) [accept larger mass baby would have to kick at a lower frequency]	(1)	2
	Total for question		12

Q18.

Question Number	Answer	Mark
(a)	Force (or acceleration): - proportional to displacement from equilibrium/undisplaced/rest position (1) - always acting towards the equilibrium/undisplaced/rest position Or always in the opposite direction to the displacement (1)	2
(b)(i)	Acceleration is a maximum at an extreme position (towards X) (1) Acceleration decreases to zero at X (1)	2
(b)(ii)	Max 3 Total energy remains constant (1) (Elastic) potential energy is transferred to kinetic energy as string moves towards X (1) Kinetic energy is zero at an extreme position and a maximum at X (1) (Elastic) potential energy is a maximum at an extreme position and a minimum at X (1)	3
(c)	Use of $\lambda = 2l$ (1) Use of $v = f\lambda$ (1) $f = 250 \text{ Hz}$ (1) <u>Example of calculation:</u> $\lambda = 2 \times 0.53 \text{ m} = 1.06 \text{ m}$ $f = v/\lambda = 270 \text{ m s}^{-1}/1.06 \text{ m} = 254.7 \text{ Hz}$	3
	Total for question	10

Q19.

Question Number	Answer	Mark
(a)(i)	Use of Newton's 2nd law ($F = ma$) with $F = -kx$ (1) Acceleration/force is in opposite direction to the displacement from the equilibrium position Or acceleration/force is (always) towards the equilibrium/undisplaced/rest position (1) <u>Example of calculation:</u> $ma = -kx$ $a = -\frac{k}{m}x$	2
(a)(ii)	See $a = -\omega^2 x$ (1) Compare with $a = -\frac{k}{m}x$ to give $\omega^2 = \frac{k}{m}$ (1) Substitute for ω using $\omega = \frac{2\pi}{T}$ (1) <u>Example of calculation:</u> $a = -\omega^2 x$ and $a = -\frac{k}{m}x$ $\omega^2 = \frac{k}{m}$ and $\omega = \frac{2\pi}{T}$ $\left(\frac{2\pi}{T}\right)^2 = \frac{k}{m} \therefore T = 2\pi\sqrt{\frac{m}{k}}$	3
(b)(i)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ (1) Use of $f = \frac{1}{T}$ (1) $f = 0.59 \text{ Hz}$ (1) <u>Example of calculation:</u> $T = 2\pi\sqrt{\frac{3.5 \times 10^5 \text{ kg}}{4.8 \times 10^6 \text{ N m}^{-1}}} = 1.7 \text{ s}$ $f = \frac{1}{T} = \frac{1}{1.7 \text{ s}} = 0.588 \text{ Hz}$	3

(b)(ii)	Correct shape Single sharp peak With the peak labelled at 0.6 Hz 	(1) (1) (1) 3
(b)(iii)	(Max) <u>amplitude</u> of oscillation is reduced as energy is transferred from the mass-spring system and then dissipated (in the surroundings)	(1) (1) (1) 3
Total for question		14