A Level AQA Physics

12 Simple harmonic motion – answers

Question	Answers	Extra information	Mark	AO	Spec reference
01.1	Period $= \frac{4.8\,\text{s}}{3} = 1.6\,\text{s}$ $f = \frac{1}{T} = \frac{1}{1.6\,\text{s}} = 0.625 = 0.63\,\text{Hz}$	Evidence of use of graph to find T Frequency	1 1	2	3.6.1.1
01.2	Maximum velocity $= \omega A = 2\pi f A$ $= 2 \times 3.14 \times 0.63 \times 0.02$ $= 0.0785\,\text{m s}^{-1} = 0.079\,\text{m s}^{-1} = (7.9 \times 10^{-2}\,\text{m s}^{-1})$	Evidence of use of frequency	1 1	1 2	3.6.1.2
01.3	Find the maximum gradient		1	1	3.4.1.3
01.4	Sinusoidal/same number of waves/frequency/periodic time Inverted/a negative cosine graph Maximum acceleration $= \omega^2 A = (2\pi f)^2 A = 0.308\,\text{m s}^{-2} = 0.31\,\text{m s}^{-2}$		1 1 1	2	3.6.1.2
01.5	Condition for simple harmonic motion is that $a \propto -x$ So the graph of a is the same shape as that of x, but inverted		1	1	3.6.1.2
02.1	Strategy: States that readings of T (as the dependent variable) will be measured for different values of independent variable, *wire diameter*, d. Clearly identifies at least 2 correct control variables: length/number of coils on spring/ mass Make springs using wire of different diameters and measure the time period Repeat measurements, omit outliers, find mean	Identifies dependent, independent and 2 control variables Change d, measure T Repeat, take mean How to deal with outliers	1 1 1 1	1	WS
02.2	Measure the time for 10 oscillations and divide the time by 10		1	2	WS
02.3	Plausible reason, e.g. the length of wire is the same so the volume/mass of the wire will vary with the area of the wire, which is proportional to d^2		1	3	3.4.2.1

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02.4	Use the time period and mass to find k $T = 2\pi\sqrt{\frac{m}{k}}$ $k = \left(\frac{2\pi}{T}\right)^2 m$ Plot a graph of k (y-axis) against d^2 (x-axis), and if it is a straight line then the hypothesis is correct	Evidence of use of equation to find k Correct axes identified	1 1	3	3.6.1.3
03.1	$T = 2\pi\sqrt{\frac{m}{k}}$ Plot a graph of T against $\sqrt{\frac{1}{k}}$: the gradient = $2\pi\sqrt{m}$ Or Plot T^2 against $\frac{1}{k}$: the gradient = $4\pi^2 m$ Collect values of time period and spring constant Change k, measure time period, use at least 6 different springs Displace the trolley and measure the time for many oscillations with a stop clock, e.g. 5, and divide by 5 to find each time period Repeat measurements and find the average time period for each value of k	Correctly identifies variables to plot, and how gradient relates to mass Indication of range of independent variable Accurate measurement of time Repeat measurements	1 1 1 1	1	3.6.1.3
03.2	Use the full reading on the stopwatch (to hundredths of a second) in measurements and calculation of the mean Round up to one decimal place, and use uncertainty in using the stopwatch = ± 0.2 s due to reaction time for both starting and stopping the stopwatch Giving a total uncertainty of ± 0.4 s	Use of full display on stopwatch until the calculation of final value Estimation of reaction time Total uncertainty is double the reaction time	1 1 1	1	WS
03.3	Suitable method: Set up the light gate so that it is horizontal and triggered by the mass when it goes through its equilibrium position Attach a straw/light rod to the mass that breaks the beam as the mass goes through its equilibrium position The measurement of T will be double the time measured by the light gate	Suitable practical arrangement Measurement of T that is accurate for the arrangement	1 1	1	3.6.1.2

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03.4	Each spring produces a restoring force of $-kx$, so the total restoring force $= -2kx$ $ma = -2kx$ compared to $ma = -kx$ so $\omega^2 = \frac{2k}{m}$, ω increases by $\sqrt{2}$ $T = \frac{2\pi}{\omega}$ so T is reduced by $\frac{1}{\sqrt{2}}$	Analysis to produce double the restoring force Use of $a = \omega^2 x$ Answer	1 1 1	2	3.6.1.2
04.1	For each length: Allow the pendulum to swing 3 times (or more) Take the times recorded by the light gate and double them to find the time period Find the mean of all of the measurements		1 1 1	1	3.6.1.3

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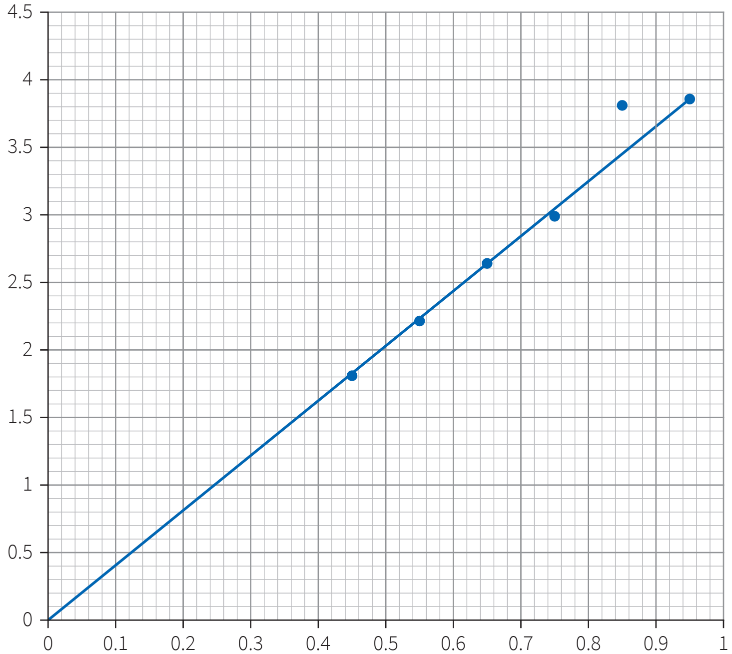
04.2	x-axis length, y-axis T^2 Line of best fit through (0, 0) 	Both labels needed	1	2	3.6.1.3
	Line of best fit ignoring anomalous result, with gradient of $\frac{4.0\,\text{s}^2}{1\,\text{m}}$	Allow 3.9–4.1	1		
	$T = 2\pi\sqrt{\frac{l}{g}}$ $T^2 = 4\pi^2\frac{l}{g}$ so graph of T^2 versus l has a gradient of $\frac{4\pi^2}{g}$	Evident of manipulation of equation	1		
	$g = \frac{4\pi^2}{\text{gradient}} = \frac{4\pi^2}{4.0} = 9.9\ (9.87)\ \text{m s}^{-2}$	Allow 9.62–10.1	1		

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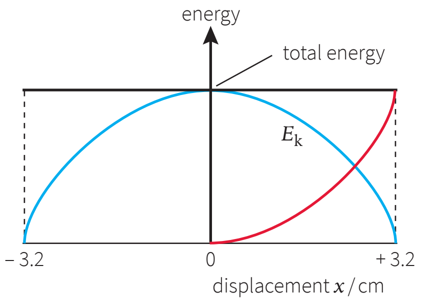
04.3	Bigger – small angle approximation does not hold, bob may fall rather than swing, time period will be shorter than it should be g will be smaller than it should be Smaller – amplitude does not affect time period, g not affected	Do not allow effect on g without explanation	1 1	1	3.6.1.3
04.4	Systematic error in measurement of length		1	2	3.4.2.2
05.1	The angle through which the pendulum is displaced should be small so that you can use the small angle approximation So that $T = 2\pi\sqrt{\frac{l}{g}}$ pendulum equation, which is independent of mass		1 1	1	3.6.1.3
05.2	$x = A\cos\omega t$ $A = 3.2 \times 10^{-2}$ m, $\omega = \frac{2\pi}{T} = \frac{2\pi}{1.4} = 4.5$ rad s^{-1} $x = 3.2 \times 10^{-2}\cos(4.5t)$	Calculation of angular velocity Equation	1 1	2	3.6.1.2
05.3	Maximum velocity = $\omega A = 4.5 \times 0.032 = 0.14$ m s^{-1} Maximum kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2} \times 0.26 \times (0.14)^2 = 2.7 \times 10^{-3}$ J Graph that is correct shape ($y = 1 - x^2$) Maximum labelled, x-axis from –3.2 cm to +3.2 cm 	Calculation of maximum kinetic energy	1 1 1	2	3.6.1.2

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05.4	Assuming the total energy is constant, the potential energy versus time graph is x^2 graph So that the kinetic energy + potential energy at any position = total energy Or Total energy $= \frac{1}{2}kA^2$ So potential energy = total energy – kinetic energy $= \frac{1}{2}kA^2 - \frac{1}{2}mv^2$	Assumption description	1 1	1	3.6.1.3
05.5	The mass decreases, so kinetic energy decreases The line will not be symmetrical/the line will reach a lower value		1	2	3.6.1.3
06.1	Bathroom scales are compressed when you stand on them by an amount that is proportional to your weight/mass In the International Space Station, both the scales and the astronaut are in free fall so the scales will not be compressed / gravitational field strength is lower		1 1	2	3.4.1.1
06.2	$T = 2\pi\sqrt{\frac{m}{k}}$ $k = m\left(\frac{2\pi}{T}\right)^2$ $= 68.62\ \text{kg} \times \left(\frac{2\pi}{2.084}\right)^2$ $= 623.8\ \text{N m}^{-1}$		1 1	2	3.6.1.3
06.3	$0.9 \times 68.62\ \text{kg} = 61.76\ \text{kg}$ $T = 2\pi\sqrt{\frac{61.76\ \text{kg}}{623.8\ \text{N m}^{-1}}}$ $= 1.977\ \text{s}$ (T is proportional to $\sqrt{m}$ so as mass decreases so does periodic time)		1 1 1	2	3.6.1.3

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OXFORD Revise

Question	Answers	Extra information	Mark	AO	Spec reference
06.4	Max displacement = amplitude, which is proportion to energy Energy transferred to thermal store due to friction		1 1	3	3.6.1.3
06.5	No The mass depends on the time period, which is independent of amplitude		1 1	1	3.6.1.3
07.1	Volume of water displaced = $A \times x = 0.75\,\text{cm}^2 \times 1.0\,\text{cm} = 0.75\,\text{cm}^3$ Mass of water = density of water × volume = $0.75\,\text{cm}^3 \times 1\,\text{g}\,\text{cm}^{-3}$ $= 0.75\,\text{g} = 7.5\times10^{-4}\,\text{kg}$ Weight = $mg = 7.5\times10^{-4}\,\text{kg} \times 9.81\,\text{N}\,\text{kg}^{-1} = 7.357..\times10^{-3}\,\text{N}$	Correct use of equations for density and weight	2	2	3.4.2.1
07.2	The restoring force is proportional to the distance that the tube is displaced from its equilibrium position OR $F = -Ag\rho x$	Explanation of $F \propto x$	1	3	3.6.1.2
07.3	Acceleration = $\frac{F}{m} = \frac{7.4\times10^{-3}\,\text{N}}{12\times10^{-3}\,\text{kg}}$ $a_{max} = 0.61\,\text{m}\,\text{s}^{-2}$ $a_{max} = \omega^2 A = (2\pi f)^2 A$ $f = \sqrt{\frac{a_{max}}{A(2\pi)^2}}$ $f = \sqrt{\frac{0.61\,\text{m}\,\text{s}^{-1}}{0.01\,\text{m}(2\pi)^2}}$ $f = 1.2(4)\,\text{Hz}$ $T = \frac{1}{f} = \frac{1}{1.24\,\text{Hz}} = 0.80\,\text{s}$	Calculation of acceleration Use of $a_{max} = \omega^2 A$ Alternatively, use $a_{max} = \omega^2 A$ to find ω, then use $T = \frac{2\pi}{\omega}$ Answer	1 1 1	3	3.6.1.2

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07.4	Restoring force $F = -Ag\rho x$ $a = -\dfrac{\text{area} \times g \times \text{density}}{\text{mass of tube}} \times x$ $\omega^2 = \dfrac{\text{area} \times g \times \text{density}}{\text{mass of tube}} = (2\pi f)^2 = \dfrac{2\pi^2}{T^2}$ density $\propto \dfrac{1}{T^2}$ A plot of density versus $\dfrac{1}{(\text{period})^2}$ is a straight line	Derivation of value of ω^2 Manipulation to show time period Answer	1 1 1	3	3.4.2.1
07.5	A series circuit with an LDR and a fixed resistor A cell/battery and a voltmeter across either the LDR or resistor		1 1	1	3.5.1.5
08.1	$k = \dfrac{F}{x} = \dfrac{700\text{ N}}{3.0 \times 10^{-2}\text{ mm}} = 23\,000\text{ N m}^{-1}$		1	2	3.4.2.1
08.2	$f = \dfrac{1}{2\pi}\sqrt{\dfrac{k}{m}} = \dfrac{1}{2\pi}\sqrt{\dfrac{23\,000}{1200}} = 0.70\text{ Hz}$ $T = \dfrac{1}{f} = \dfrac{1}{0.70} = 1.4(2)\text{ s}$		1 1	2	3.6.1.3
08.3	If the car goes over a bump/speed bump, it will displace the car from its equilibrium position		1	3	3.6.1.2
08.4	$T = 2\pi\sqrt{\dfrac{m}{k}}$ Either: plot T^2 versus m, gradient $= \dfrac{4\pi^2}{k}$ Or: plot T versus $\sqrt{m}$, gradient $= 2\pi\sqrt{\dfrac{1}{k}}$	Appropriate plot Gradient that matches plot	1 1	1	3.6.1.3
08.5	The oscillations are heavily/critically damped		1	2	3.6.1.4

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OXFORD Revise

Skills box answers

Question	Answer
1	Use a fiducial marker (such as a pin) stuck at the equilibrium point of the mass. Reduce parallax by observing oscillation at the same level as the fiducial marker/mass. Use small displacements of the mass so that the mass hanger doesn't 'jump' at the minimum displacement of the oscillation. Include a measurement of reaction time in the measured time period.