CAMBRIDGE INTERNATIONAL A LEVEL • PHYSICS 9702

Topical Questions

Unit 17: Oscillations

Past Papers 2021 – 2025

MARK SCHEME 23 Questions

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Question 1 — Mark Scheme

9702/41 Cambridge International AS & A Level – Mark Scheme October/November 2021
PUBLISHED

Question	Answer	Marks
4(a)(i)	5.0 cm	**A1**
4(a)(ii)	$\omega = 2\pi / T$ **or** $\omega = 2\pi f$ **and** $f = 1 / T$	**C1**
	$\omega = 2\pi / 4.0$ $= 1.6$ rad s^{-1}	**A1**
4(a)(iii)	$v_0 = \omega x_0$	**C1**
	$= 1.57 \times 5.0$ $= 7.9$ cm s^{-1}	**A1**
4(b)	• initial pull was to the right • distance from X to trolley (at equilibrium) is 20 cm • period is 4.0 s • initial motion undamped • motion becomes damped at/from 12 s • damping is light • maximum speed at 1 s, 3 s, etc. / stationary at 2 s, 4 s, etc. *Any three points, 1 mark each*	**B3**
4(c)	sketch: closed loop encircling (20, 0)	**B1**
	minimum L shown as 15 cm and maximum L shown as 25 cm	**B1**
	minimum v shown as –7.9 cm s^{-1} and maximum v shown as +7.9 cm s^{-1}	**B1**

Question 2 — Mark Scheme

9702/42 Cambridge International AS & A Level – Mark Scheme October/November 2021
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Question	Answer	Marks
4(a)	straight line through the origin	**B1**
	negative gradient	**B1**
4(b)	$a = (-)\omega^2 x$ **and** $T = 2\pi / \omega$	**C1**
	e.g. $\omega = \sqrt{(0.80 / 0.12)}$ (*any correct pair of values of a and x*) $(= 2.58 \text{ rad s}^{-1})$	**C1**
	$T = 2\pi / 2.58$ $= 2.4 \text{ s}$	**A1**
4(c)(i)	Point labelled P at one end of the line	**B1**
4(c)(ii)	Point labelled Q at displacement with magnitude more than half but less than maximum	**B1**

Question 3 — Mark Scheme

9702/41 Cambridge International AS & A Level – Mark Scheme May/June 2021
PUBLISHED

Question	Answer	Marks
3(a)	acceleration (directly) proportional to displacement	**B1**
	acceleration is in opposite direction to displacement	**B1**
3(b)	$\omega^2 = 2k/m$ **and** $\omega = 2\pi f$	**C1**
	$(2\pi f)^2 = (2 \times 130)/0.84$	**C1**
	$f = 2.8$ Hz	**A1**
3(c)(i)	resonance	**B1**
3(c)(ii)	oscillator supplies energy (continuously)	**B1**
	energy of trolley constant so energy must be dissipated **or** without loss of energy the amplitude would continuously increase	**B1**

Question 4 — Mark Scheme

9702/42 Cambridge International AS & A Level – Mark Scheme **PUBLISHED** May/June 2021

Question	Answer	Marks
3(a)	acceleration in opposite direction to displacement shown by – sign	B1
	g / L is constant	M1
	(so) acceleration is (directly) proportional to displacement	A1
3(b)	$\omega^2 = g / L$	C1
	$\omega = 2\pi / T$ **or** $\omega = 2\pi f$ **and** $f = 1 / T$	C1
	$(2\pi / T)^2 = 9.81 / 0.18$ $T = 0.85$ s	A1
3(c)	energy $\propto x_0^2$	C1
	(after 3 cycles,) amplitude $= (0.94)^3 x_0$ $= 0.83 x_0$	C1
	ratio final energy / initial energy $= 0.83^2$ $= 0.69$	A1

Question 6 — Mark Scheme

Question	Answer	Marks
2(d)(ii)	volume increases and work is done by the gas	B1
	temperature decreases and internal energy decreases	B1

Question	Answer	Marks
3(a)	upthrust, weight	B1
3(b)	upthrust greater than weight so (resultant force is) upwards	B1
3(c)(i)	A, g and ρ all constant so $F \propto x$	B1
	minus sign means F and x are in opposite directions	B1
3(c)(ii)	$\left(a = \frac{F}{m}\right.$ so) $a = (-)\frac{A g \rho x}{m}$	M1
	so $\omega^2 = \frac{A g \rho}{m}$ hence $\omega = \sqrt{\frac{A g \rho}{m}}$	A1
3(d)(i)	damping due to viscous forces	B1
3(d)(ii)	$(E =) \frac{1}{2} m \omega^2 x_0^2$	C1
	ω^2 = (–) gradient	C1
	$(E =) \frac{1}{2} m \omega^2 (x_1^2 - x_2^2)$ $= \frac{1}{2} \times 0.57 \times \left(\frac{2.3}{0.020}\right)^2 (0.020^2 - 0.016^2)$ $= 4.7 \times 10^{-3}$ J	A1

Question 7 — Mark Scheme

Question	Answer	Marks
4(a)	straight line through origin shows that *a* is proportional to *x*	**B1**
	negative gradient shows that *a* is in opposite direction to *x*	**B1**
4(b)(i)	$a_0 = \omega^2 x_0$ **or** $a = -\omega^2 x$ **or** ω^2 = – gradient	**C1**
	$\omega = \sqrt{(0.40 / 0.050)}$ $= 2.8$ rad s^{-1}	**A1**
4(b)(ii)	$k = \omega^2 L$ $= 2.8^2 \times 1.24$	**C1**
	$= 9.7$ m s^{-2}	**A1**
4(c)	(increasing *L* causes) ω to decrease **or** energy ($= \frac{1}{2} m\omega^2 x_0^2$) $= \frac{1}{2} mkx_0^2 / L$ (and *L* increases)	**M1**
	so amplitude increases	**A1**

Question 8 — Mark Scheme

Question	Answer	Marks
4(a)	oscillations (of object) at maximum amplitude	**B1**
	when driving frequency equals natural frequency (of object)	**B1**
4(b)(i)	$T = 2\pi / \omega$	**C1**
	$= 2\pi / 5.0\pi$ $= 0.40$ s	**A1**
4(b)(ii)	displacement scale labelled –1.0, –0.5, (0), 0.5, 1.0 on the 2 cm tick marks	**B1**
	t scale labelled 0.2, 0.4, 0.6, 0.8, 1.0, 1.2 on the 2 cm tick marks	**B1**
4(b)(iii)	$\phi = 2\pi\Delta t / T$ $= 2\pi \times 0.10 / 0.40$ **or** $2\pi \times 0.30 / 0.40$	**C1**
	= 1.6 rad **or** 4.7 rad	**A1**

Question 9 — Mark Scheme

Question	Answer	Marks
3(a)	$a = -\omega^2 x$	**M1**
	a = acceleration, x = displacement from equilibrium position and ω = angular frequency	**A1**
3(b)(i)	$x_0 = 0.12$ m	**A1**
3(b)(ii)	$v = \omega\sqrt{(x_0^2 - x^2)}$ two (x, v) pairs correctly read from Fig. 3.2 (one may be (x_0, 0) or value of x_0 from **(i)**)	**C1**
	e.g. $0.20 = \omega\sqrt{(0.12^2 - 0)}$ leading to $\omega = 1.7$ rad s^{-1}	**A1**
3(b)(iii)	$E = \frac{1}{2}M\omega^2 x_0^2$	**C1**
	$0.050 = \frac{1}{2} \times M \times 1.67^2 \times 0.12^2$ $M = 2.5$ kg	**A1**
	or	
	$(E_K)_{max} = \frac{1}{2}Mv_0^2$	**(C1)**
	$0.050 = \frac{1}{2} M \times 0.20^2$ $M = 2.5$ kg	**(A1)**
3(c)(i)	loss of (total) energy (of system)	**B1**
	due to resistive forces	**B1**
3(c)(ii)	closed loop surrounding the origin with maximum x at ± 0.060 m passing through $v = 0$	**B1**
	maximum velocity shown as ± 0.10 m s^{-1} passing through $x = 0$	**B1**

Question 10 — Mark Scheme

Question	Answer	Marks
4(a)(i)	$x_0 = 8.0$ cm	**A1**
4(a)(ii)	$\omega = 2\pi / T$	**C1**
	$= 2\pi / 4.0 = 1.6$ rad s^{-1}	**A1**
4(a)(iii)	$E = \frac{1}{2}m\omega^2 x_0^2$	**C1**
	$= \frac{1}{2} \times 36 \times 1.6^2 \times 0.080^2$	**C1**
	$= 0.29$ J	**A1**
4(b)	dome-shaped curve, starting and ending at $E_K = 0$	**B1**
	maximum E_K shown as 0.29 J	**B1**
	position of peak shown at $h = 10.0$ cm	**B1**
	line intercepts h-axis at $h = 2.0$ cm and at $h = 18.0$ cm	**B1**

Question 11 — Mark Scheme

9702/42 Cambridge International AS & A Level – Mark Scheme February/March 2023
PUBLISHED

Question	Answer	Marks
3(a)	P: total energy Q: potential energy R: kinetic energy	**B2**
3(b)	$E = \frac{1}{2}m\omega^2 x_0^2$ **or** $E = \frac{1}{2}mv_0^2$ **and** $v_0 = \omega x_0$	**C1**
	$6.4 \times 10^{-3} = \frac{1}{2} \times 0.130 \times \omega^2 \times 0.015^2$ $(\omega^2 = 438)$ $(\omega = 20.9)$	**C1**
	$T = 2\pi / \omega$	**C1**
	$= 2\pi / 20.9$ $= 0.30$ s	**A1**
3(c)(i)	resistive forces	**B1**
3(c)(ii)	0.92^6	**C1**
	decrease in energy $= 6.4 - (6.4 \times 0.92^6)$ $= 2.5$ mJ	**A1**
3(c)(iii)	light damping because the amplitude of oscillations gradually reduces **or** light damping because the system still oscillates	**B1**

Question 12 — Mark Scheme

Question	Answer	Marks
2(a)	horizontal force on sphere causes centripetal acceleration	**B1**
	weight of sphere is (now) equal to vertical component of tension **or** horizontal and vertical components (of force) (now) combine to give greater tension (in spring)	**B1**
	greater tension in spring so greater extension of spring	**B1**
2(b)(i)	$r = 10.8 \times \sin 27° = 4.9$ cm	**A1**
2(b)(ii)	$T \cos \theta = mg$ **or** $T \cos \theta = W$ **and** $W = mg$	**C1**
	$T \cos 27° = 0.29 \times 9.81$ leading to $T = 3.2$ N	**A1**
2(b)(iii)	$\Delta T = 3.2 - (0.29 \times 9.81)$	**C1**
	$k = \Delta T / \Delta x$ $= [3.2 - (0.29 \times 9.81)] / [10.8 - 8.5]$ $= 0.15$ N cm^{-1}	**A1**
2(c)(i)	centripetal acceleration $= (T \sin \theta) / m$ $= (3.2 \times \sin 27°) / 0.29$	**C1**
	$= 5.0$ m s^{-2}	**A1**

Question	Answer	Marks
2(c)(ii)	$a = r\omega^2$ **and** $\omega = 2\pi / T$ **or** $a = v^2 / r$ **and** $v = 2\pi r / T$	**C1**
	$T = 2\pi \times \sqrt{(0.049 / 5.0)}$ $= 0.62$ s	**A1**

Question 13 — Mark Scheme

Question	Answer	Marks
4(a)(i)	$\omega = 2\pi f$	C1
	$f = 9.7 / 2\pi$ $= 1.5$ Hz	A1
4(a)(ii)	amplitude = $\sqrt{(11.6)} = 3.4$ cm	A1
4(a)(iii)	$a_0 = \omega^2 x_0$	C1
	$= 9.7^2 \times 3.4 \times 10^{-2}$ $= 3.2$ m s^{-2}	A1
4(b)	sketch: straight line through the origin with negative gradient	B1
	line with negative gradient passing through (+3.4, $-a_0$) and (–3.4, $+a_0$)	B1
	line with ends at $x = \pm 3.4$ cm and $a = \pm a_0$	B1
4(c)	sum of potential energy and kinetic energy is constant	B1
	at maximum displacement, kinetic energy is zero **or** at maximum displacement, potential energy is maximum	B1
	at zero displacement, kinetic energy is maximum **or** at zero displacement, potential energy is minimum	B1

Question 14 — Mark Scheme

Question	Answer	Marks
4(a)	(motion in which) acceleration is (directly) proportional to displacement	**B1**
	(motion in which): acceleration is (always) in the opposite direction to displacement **or** acceleration is (always) directed towards a fixed point	**B1**
4(b)(i)	$\omega = 2\pi / T$	**C1**
	$\omega = 2\pi / 3.0$ $= 2.1 \text{ rad s}^{-1}$	**A1**
4(b)(ii)	$E = \frac{1}{2}m\omega^2 x_0^2$	**C1**
	$= \frac{1}{2} \times 0.81 \times 2.1^2 \times 0.036^2$ $= 2.3 \times 10^{-3} \text{ J}$	**A1**
4(c)	sketch: line starting at (0, 0.036) and not reaching $x = \pm 0.036$ m at any other time	**B1**
	smooth curve, with no sudden changes in gradient, showing continuously decreasing magnitude of x from maximum displacement at $t = 0$ to final displacement of zero where the gradient is also zero	**B1**
	displacement reaches final value of zero between $t = 0.75$ s and $t = 3.0$ s at the latest	**B1**

Question 15 — Mark Scheme

Question	Answer	Marks
3(a)	$E = \frac{1}{2} m\omega^2 x_o^2$	C1
	$2.2 \times 10^{-4} = \frac{1}{2} \times 24 \times 10^{-3} \times (14 \times 10^{-3} / 4)^2 \times \omega^2$	C1
	$\omega = 39$ rad s^{-1}	A1

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Question	Answer	Marks
3(b)(i)	use of acceleration = 9.81 m s^{-2} $x_o = 9.81 / 39^2$	C1
	$= 6.4 \times 10^{-3}$ m	A1
3(b)(ii)	at top of oscillation	B1
	any one point from: where the downward acceleration first exceeds free-fall acceleration where the greatest downwards acceleration occurs where the resultant force is the maximum downwards where the contact force is a minimum	B1

Question 16 — Mark Scheme

9702/41 Cambridge International AS & A Level – Mark Scheme **PUBLISHED** May/June 2024

Question	Answer	Marks
4(a)	oscillation (of object) at maximum amplitude	B1
	when driving frequency = natural frequency (of system)	B1
4(b)(i)	light damping	B1
4(b)(ii)	oscillations (of ball) lose energy	B1
	(due to) resistive forces (acting on ball)	B1
4(b)(iii)	frequency = 1 / 0.25 = 4.0 Hz	A1
4(c)	curve showing a maximum amplitude at a single non-zero frequency	B1
	single maximum amplitude shown at 4.0 Hz	B1

Question 17 — Mark Scheme

Question	Answer	Marks
4(a)	straight line through the origin shows that a is proportional to x	B1
	negative gradient shows that a and x are (always) in opposite directions	B1
4(b)(i)	$a = -\omega^2 x$ $\omega = \sqrt{(2A / 3Y)}$	A1
4(b)(ii)	$v_0 = \omega x_0$	C1
	$= 3Y \times \sqrt{(2A / 3Y)}$ $= \sqrt{(6AY)}$	A1
4(b)(iii)	$E = ½ m\omega^2 x_0^2$	C1
	$= ½ m \times (2A / 3Y) \times (3Y)^2$ $= 3mAY$	A1
4(c)	$\omega = 2\pi / T$ $(= 2\pi / 0.75)$	C1
	$x = 1.8 \sin (8.4 t)$	A1

Question 18 — Mark Scheme

9702/41 Cambridge International AS & A Level – Mark Scheme October/November 2024
PUBLISHED

Question	Answer	Marks
4(a)	(motion in which) acceleration is (directly) proportional to displacement	**B1**
	(motion in which): acceleration is (always) in the opposite direction to displacement **or** acceleration is (always) directed towards a fixed point	**B1**
4(b)(i)	amplitude = (9.5 – 3.5) / 2 = 3.0 cm	**A1**
4(b)(ii)	$\omega = v_0 / x_0$	**C1**
	= 9.5 / 3.0 = 3.2 rad s^{-1}	**A1**
4(b)(iii)	$T = 2\pi / \omega$	**C1**
	= 2π / 3.2 = 2.0 s	**A1**
4(b)(iv)	attempted sinusoidal curve starting with a minimum at $t = 0$	**B1**
	sinusoidal curve of period 2.0 s from $t = 0$ to $t = 6.0$ s	**B1**
	all peaks shown at $h = 9.5$ cm	**B1**
	all troughs shown at $h = 3.5$ cm	**B1**

Question 19 — Mark Scheme

Question	Answer	Marks
5(a)	arrow from sphere, perpendicular to string, pointing left and down	B1
5(b)(i)	amplitude = 0.016 m	A1
5(b)(ii)	angular frequency = $2\pi / T$	C1
	$= 2\pi / 0.40$ $= 16$ rad s^{-1}	A1
5(b)(iii)	total energy = $\frac{1}{2}m\omega^2 x_0^2$	C1
	$= \frac{1}{2} \times 0.15 \times 15.7^2 \times 0.016^2$ $= 4.7 \times 10^{-3}$ J	A1
5(c)	dome-shaped curve starting and ending on the x-axis, with peak at $x = 0$	B1
	maximum E_K shown as 4.7×10^{-3} J	B1
	minimum x shown as –0.016 m and maximum x shown as +0.016 m at the ends of the line	B1

Question 20 — Mark Scheme

9702/41 Cambridge International AS & A Level – Mark Scheme May/June 2025
PUBLISHED

Question	Answer	Marks
5(a)(i)	amplitude = 0.60 m	**A1**
5(a)(ii)	oscillations are simple harmonic	**B1**
5(b)	*Any three points from:* • mean / equilibrium position is at h = 1.4 m • total energy of oscillations = 9.0 J • angular frequency of oscillations = 1.2 rad s^{-1} **or** period of oscillations = 5.1 s **or** frequency of oscillation = 0.19 Hz • maximum speed of block = 0.73 m s^{-1} • mass of block = 33 kg	**B3**
5(c)	U-shaped curve resting on h axis (with minimum at E_P = 0)	**B1**
	curve from h = 0.8 m to h = 2.0 m, with minimum E_P shown at h = 1.4 m	**B1**
	both end-points of curve shown at E_P = 9.0 J	**B1**

Question 21 — Mark Scheme

9702/42 Cambridge International AS & A Level – Mark Scheme **PUBLISHED** May/June 2025

Question	Answer	Marks
5(a)	(motion in which) acceleration is (directly) proportional to displacement	B1
	(motion in which) acceleration is (always) in the opposite direction to displacement **or** acceleration is (always) directed towards a fixed point	B1
5(b)(i)	period $= 2\pi / 16$ $= 0.39$ s	A1
5(b)(ii)	$v_0 = \omega x_0$ **or** $v_0 = \omega\sqrt{(x_0^2 - 0^2)}$	C1
	$x_0 = 0.56 / 16$ $= 0.035$ m	A1
5(b)(iii)	$v = \pm 16\sqrt{(0.0352 - x^2)}$	A1
5(b)(iv)	closed loop surrounding the origin	B1
	loop crosses $v = 0$ at maximum values of x at $x = \pm 3.5$ cm	B1
	loop crosses $x = 0$ at maximum values of v at $v = \pm 0.56$ m s^{-1}	B1

Question 22 — Mark Scheme

Question	Answer	Marks
4(a)	(motion in which) acceleration is (directly) proportional to displacement	B1
	(motion in which) acceleration is (always) in the opposite direction to displacement **or** acceleration is (always) directed towards a fixed point	B1
4(b)(i)	t_1 **and** t_5 **or** t_3 **and** t_7	B1
4(b)(ii)	$f = 1 / T$	C1
	period = 2.2 / 1.25 f = 1.25 / 2.2 = 0.57 Hz	A1
4(c)	$v_0 = \omega x_0$ **and** $\omega = 2\pi f$	C1
	$0.080 = 2\pi \times 0.57 \times x_0$	C1
	$x_0 = 0.022$ m	A1

Question 23 — Mark Scheme

9702/42 Cambridge International AS & A Level – Mark Scheme October/November 2025
PUBLISHED

Question	Answer	Marks
5(a)(i)	straight line through the origin shows that a is proportional to x	**B1**
	negative gradient shows that a is always in the opposite direction to x	**B1**
5(a)(ii)	$a_0 = \omega^2 x_0$	**C1**
	$\omega = 2\pi / T$	**C1**
	$T = 2\pi \sqrt{(x_0 / a_0)}$ $= 2\pi \sqrt{(1.2 / 13)}$ $= 1.9$ s	**A1**
5(b)(i)	loss of energy of oscillations	**B1**
	due to resistive force(s)	**B1**
5(b)(ii)	line starting from $x = \pm 1.2$ cm at $t = 0$	**B1**
	line starting from non-zero value of x from $t = 0$ to $t = 2T$ that is entirely either above or below the t-axis	**B1**
	curve from $t = 0$ starting from non-zero x value, with both magnitude of x value and magnitude of gradient continuously decreasing	**B1**

Question 24 — Mark Scheme

Question	Answer	Marks
4(a)	number of oscillations per unit time	B1
4(b)(i)	kinetic energy (of object) reaches maximum / minimum / zero twice in a cycle	A1
4(b)(ii)	$\omega = 2\pi / T$ $= 2\pi / 0.80$ **or** $a_0 = \omega^2 x_0$ $\omega = \sqrt{(1.0 / 0.016)}$	C1
	$\omega = 7.9$ rad s^{-1}	A1
4(b)(iii)	*Any three points from:* • oscillations are simple harmonic • amplitude = 0.016 m • maximum speed = 0.13 m s^{-1} • total energy of oscillations = 7.0×10^{-4} J • mass of object = 0.087 kg • maximum momentum = 0.011 kg m s^{-1} **or** 0.011 N s	B3

Question	Answer	Marks
4(b)(iv)	*Any two points from:* • kinetic energy is a maximum at zero displacement **or** kinetic energy is zero at maximum displacement • potential energy is zero at zero displacement **or** potential energy is a maximum at maximum displacement • kinetic energy is maximum when the potential energy is zero **or** potential energy is a maximum when the kinetic energy is zero	**B2**
	kinetic energy + potential energy is constant	**B1**

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