A LEVEL
Physics

PHA6/B6/X – Investigative and practical skills in A2 Physics

Mark Scheme

2450/2455
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Version 1: Final Mark Scheme

AQA

PHYAB6: Practical and Investigative Skills in A2 Physics

Section A Task 1				
1	(a) (i) and (ii)	results:	T_1 and T_2, each from nT where n or $\Sigma n \geq 20$, consistent recording of nT sensible values to 0.1 s or 0.01 s T_1 must be > T_2 ✓ withhold this mark if the same criteria are not applied in question 2 where T_3 must be > T_4 withhold mark if no unit is seen in 1(a) and in 2(a)(i)/(ii)	**1**
	(b)(i)	assumption:	springs have same stiffness [spring constant] ✓	**1**
	(b)(ii)	method:	evaluates k_1 and k_2; correct substitution of T_1, T_2 and m ₁✓ (allow m = 200 g and don't penalise for missing / wrong unit for k) **correctly** evaluates $\frac{k_2}{k_1}$ and compares with 2 [**correctly** calculates percentage difference between $\frac{k_2}{k_1}$ and predicted outcome (of 2) / correctly evaluates $2k_1$ and compares with k_2 etc] ₂✓ [evaluates $\sqrt{2} \times \frac{T_2}{T_1}$ ₁✓; compares with 1 [**correctly** calculates percentage difference between $\sqrt{2} \times \frac{T_2}{T_1}$ and predicted outcome (of 1) ₂✓] [evaluates T_2^2 and T_1^2 ₁✓; **correctly** evaluates $\frac{T_1^2}{T_2^2}$ [**correctly** calculates percentage difference between $\frac{T_1^2}{T_2^2}$ and predicted outcome (of 2) ₂✓] [evaluates T_2^2 and T_1^2 ₁✓; **correctly** evaluates $2 \times \frac{T_2^2}{T_1^2}$ [**correctly** calculates percentage difference between result and predicted outcome (of 1) ₂✓]	**2**
		conclusion:	result in (a) produces $\left(\frac{T_1}{T_2}\right)^2$ in range 1.95 to 2.05 or 2.0 ₃✓ states that prediction is correct ₄✓ [result in (a) produces $\left(\frac{T_1}{T_2}\right)^2$ < 1.90 or > 2.10; states that prediction is incorrect ₃₄✓; $\left(\frac{T_1}{T_2}\right)^2$ between 1.90 to 1.95 or between 2.05 to 2.10; can state either that prediction is correct or incorrect ₃₄✓]	**2**

1	(c)(i)	explanation:	use of average increase in period = 3.2 % $_1$✓ $T^2 \propto m \quad \therefore 1.032^2 = \frac{m+d}{m}$ where m = 0.200 kg [200 g] and d = mass of dvd $_2$✓ solves to <u>show</u> d = 13(.0) g $_3$✓ [$T^2 \propto m \quad \therefore 1.031^2 = \frac{m+d}{m}$ to show d = 12.6 g **or** $T^2 \propto m \quad \therefore 1.033^2 = \frac{m+d}{m}$ to show d = 13.4 g earns $_{23}$✓✓; for both calculations <u>and averaging</u> leading to d = 13(.0) g $_1$✓]	3
			[use of 1.031T_1 with correct substitution of T_1 and k_1 (and 2π) to calculate new mass (found in (b)(ii)); d = new mass – 0.200 kg; solves to show $d \approx$ 13(.0) ± 1(.0) g **or** use of 1.033T_2 with correct substitution of T_2 and k_2 (and 2π) etc to show $d \approx$ 13(.0) ± 1(.0) g earns $_{23}$✓✓; for both calculations and averaging leading to d = 13(.0) ± 1(.0) g $_1$✓] (note that results obtained using own data may not work out to be 12.6 and 13.4; allow for truncated k values)	
	(c)(ii)	explanation:	student has not taken account of the mass of the nut [bolt / hooks / paperclips] ✓	1

2	(a)(iii)	accuracy:	*k* in range 3.74 to 4.58 or 2sf between 3.8 and 4.5 $_1$✓ m^{-2} $_2$✓ (answers with cm^{-2} should be ×10^{-4}) **max 4sf: note that this is the only part of Section A where excessive sf are penalised** for x_2 = 300 mm mark as follows: *k* in range 3.81 to 4.65 or 2sf between 3.9 and 4.6 $_1$✓	**2**
	(b)	explanation:	valid procedure $_1$✓ with appropriate explanation $_2$✓ • explanation mark is only awarded when it is relevant to a correct procedure • one procedure/explanation allowed per response • no credit for conflicting statements or wrong physics any two from: time multiple oscillations [lengthen time over which timing carried out] $_1$✓ to reduce percentage error (condone 'uncertainty' (in period)) [to reduce the impact [effect] of human [random] error / reaction time] $_2$✓ and/or repeat (timing measurements) $_1$✓ to detect anomalous results so these can be eliminated $_2$✓ (reject 'to reduce impact [effect] of anomalous results') and/or use 'count down' technique $_1$✓ to reduce chance of systematic error [miscounting cycles] $_2$✓ and/or set oscillator in motion but wait before starting timing [until transient oscillations have dissipated] $_1$✓ to ensure period is constant $_2$✓ and/or use a fiducial mark at the centre of oscillation (can be shown in a sketch but the fiducial mark must be at the free end of the ruler) $_1$✓ since this is where transit time is least [oscillator is moving fastest] $_2$✓ and/or view oscillations at right angles to the motion $_1$✓ to reduce parallax error $_2$✓ and/or ensured that amplitude of oscillations was small $_1$✓ so period was constant [to ensure shm / to ensure springs obey Hooke's Law] $_2$✓	**MAX 4**
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Section A Task 2

1	(a)	accuracy:	V_0, value sensible, to nearest 0.1 V or to nearest 0.01 V ✓ deduct SF mark in (b) if inconsistent precision between (a) and (b); unit must be supplied	**1**
1	(b)	tabulation:	V_1 / V V_2 / V t /s ✓ deduct this mark for any missing label or separator; accept all data in one single table or separate tables for V_1 and V_2 with t to appear in each (don't penalise here and in (a) for missing unit with V)	**1**
		results:	at least 7 sets of V_1 and t including t = 0, V_1 = V_0 (± 1%) and t = 60 (eg average interval of 10 s) $_1$✓ at least 7 sets of V_2 and t including t = 0, V_2 = 0(.00), and t = 60 (eg average interval of 10 s) $_2$✓ at least 6 sets of V_1 and 6 sets of V_2, average interval of 10 s but missing t = 0 data $_{12}$✓ <u>both</u> V_1 <u>and</u> V_2 from repeated readings $_3$✓ deduct 1 mark if t is not in the left-hand column of a coherent table [in two tables if V_1 and V_2 are shown separately / in the top row where the data is arranged in rows]	**3**
		significant figures:	all (raw) V to nearest 0.1 V or all to nearest 0.01 V; tolerate V_2 = 0 (ie 1 sf) at t = 0 ✓	**1**
	(c)	axes:	marked V/V (vertical) and t/s (horizontal) ✓✓ deduct ½ for each missing label or separator, rounding down; no mark if axes reversed either or both marks may be lost if the interval between the numerical values is marked with a frequency of > 5 cm	**2**
		scales:	points should cover at least half the grid horizontally ✓ <u>and</u> half the grid vertically ✓ (the origin must be shown on this graph unless the t = 0 data set has not been tabulated; either or both marks may be lost for use of a difficult or non-linear scale)	**2**
		points:	all tabulated points plotted correctly (check at least two on each line including any anomalous points) ✓✓✓ 1 mark is deducted for every point missing and for every point > 1 mm from correct position deduct 1 mark if any point is poorly marked; no credit for false data	**3**
		V_1 line and quality:	smooth curve of decreasing negative gradient commencing at V_1 = V_0 at t = 0 s and continuing to t = 60 s, <u>suitably labelled</u>; at least 6 points to ± 2 mm of a suitable line, adjusting for any mis-plots; adjust ± 2 mm criterion if the graph is poorly scaled ✓	**1**

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		V_2 line and quality:	smooth curve of decreasing positive gradient rising from $V_2 = 0$ at $t = 0$ s to a peak between $t = 25$ s and $t = 40$ s then smooth curve of increasing negative gradient continuing to $t = 60$ s, suitably labelled; at least 6 points to ± 2 mm of a suitable line, adjusting etc ✓	**1**
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Section B			
1	(a)(i)	valid attempt at gradient calculation and correct transfer of data **or** $_{12}$✓ **= 0** tangent [normal] drawn to V_2 curve where $V_1 = V_2$ and correct transfer of y- and x-step between graph and calculation $_1$✓ (mark is withheld if points used to determine either step > 1 mm from correct position on grid; if tabulated points are used these must lie on the line) y-step and x-step both at least 8 semi-major grid squares [5 by 13 or 13 by 5] $_2$✓ (if a poorly-scaled graph is drawn the hypotenuse of the gradient triangle should be extended to meet the 8 × 8 criteria)	**2**
1	(a)(ii)	$\frac{V_e}{G}$, at least 2 sf, in range 35.2 s to 47.6 s [accept 2 sf in range 36 to 47] ✓✓ [29.0 s to 53.8 s or 2 sf in range 30 to 35, or in range 48 to 53 ✓]	**2**
1	(b)(i)	$\frac{R_2}{R_1}$, no unit, in range 2.03 to 2.25, 2.1 or 2.2 ✓ **min 2 sf and max 4sf answer: note that this is the only part of Section B where excessive sf are penalised**	**1**
1	(b)(ii)	V_1 contributes most to the percentage uncertainty in $\frac{R_2}{R_1}$ **or 0/2**: (when V_2 is a maximum) V_1 is smaller (than V_2) $_1$✓ idea that a small error in the estimation of the time where V_2 is a maximum produces a large error in V_1 $_2$✓	**2**
1	(b)(iii)	tick next to **No current is flowing** (only); accept other clear means of identifying this response ✓	**1**
1	(b)(iv)	(since $\frac{V_2}{V_1} = \frac{R_2}{R_1}$) current in R1 = current in R2 $_1$✓ current flowing in to terminal Y = current flowing out of terminal Y (hence no current can flow to C2 from Y or in to Y from C2) $_2$✓ ——— [from $\left(Q = C \times V;\ \frac{dQ}{dt} = C \times \frac{dV}{dt};\therefore\right)\ I = C \times \frac{dV}{dt}$ $_1$✓ when $\frac{dV}{dt} = 0$, $I = 0$ $_2$✓] ——— [current reverses after the moment that V_2 is a maximum **or** before (V_2 is a maximum) the current is towards C2 [away from Y / C2 charges up] **and** after (V_2 is a maximum) the current is away from C2 [towards Y / current reverses / C2 discharges] $_{12}$✓ = 1 MAX]	**2**

1	(c)	curve of decreasing negative gradient (allow straight line of negative gradient) starting at (0, 3.95 ± 0.05) $_1$✓ ending at (60, 2.70 ± 0.05) $_2$✓	**2**

2	(a)	systematic error in *y* would produce a (non-zero) intercept [graph is transformed / line shifted / points shifted by the same amount] ✓	**1**
	(b)(i)	either kg s^{-2} or N m^{-1} or J m^{-2} ✓	**1**
	(b)(ii)	gradient is increased [steeper] or 0/2 $_1$✓ (for same x,) y values are proportionally bigger [bigger by same fraction], or (for same y,) x values are proportionally smaller [smaller by same fraction, or because $\frac{2s\gamma}{g t\rho}$ is the gradient] $_2$✓	**2**
	(c)	plot $\left(h+\frac{r}{3}\right)$ against $\frac{1}{r}$ or vice-versa; the suggested plot must be linear $_1$✓ [other variations are possible] valid method of obtaining γ using the gradient of the graph, eg for $\left(h+\frac{r}{3}\right)$ on vertical axis against $\frac{1}{r}$, gradient = $\frac{2\gamma}{g\rho}$ (hence γ = gradient × $\frac{g\rho}{2}$) $_2$✓	**2**
	(d)(i)	l_1 (= $R_2 - R_1$ = 11.51 – 2.92) = 8.59 cm and l_2 (= $R_4 - R_3$ = 9.07 – 3.85) = 5.22 cm [$l_1 - l_2$ = 3.37 cm] $_1$✓ (reject truncation to 2sf 8.6 and 5.2) method: $r=\sqrt{\frac{m}{\rho\pi(l_1-l_2)}}$ $\left[r^2=\frac{m}{\rho\pi(l_1-l_2)}\right]$ $_2$✓ *r* = 1.36 × 10^{-3} m [1.359 × 10^{-3} m to 4sf] $_3$✓ (ecf for wrong $_1$✓ but no credit for POT errors; reject 2sf 1.4 × 10^{-3} m unless data has been truncated to lose $_1$✓)	**3**
	(d)(ii)	uncertainty in ($l_1 - l_2$) = ± 0.20 cm $_1$✓ percentage uncertainty in ($l_1 - l_2$) = $\left[\frac{0.20}{3.37}\times 100\right]$ (= 5.9(3) % or 6 %) $_2$✓ (ecf if uncertainty in ($l_1 - l_2$) = ± 0.10 cm) percentage uncertainty in *r* (= 0.5 × percentage uncertainty in ($l_1 - l_2$)) =2.9(7) % [accept 2sf 3.0 % or 1sf 3 %] $_3$✓ (ecf for wrong $_2$✓; reject 2.9 %)	**3**
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