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General Certificate of Education (A-level)
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Physics **PHA6/B6/X**

Unit 6: Investigative and practical skills in A2 Physics

Final

Mark Scheme

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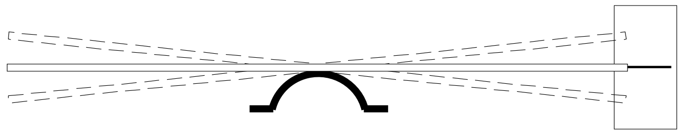
GCE Physics, PHA6/B6/X, Investigative and Practical Skills in A2 Physics

Section A, Part 1

Question 1				
1	(i)	method:	at least three (raw) readings of diameter to 0.01 mm, valid average (diameter or radius) calculated ✓	**1**
		accuracy:	all raw reading(s) of diameter in the range 11.92 mm to 12.08 mm ✓ (don't penalise for failure to convert diameter to radius since this is penalised in (iii))	**1**
1	(ii)	method:	T_1, result sensible, eg about 0.65 s, from nT_1, where n or $\Sigma n \geq 30$; nT_1 to 0.1 s or 0.01 s ✓ (reject T from oscillations in a fixed time; if no unit is found in the working and/or answer for T_1 and for T_2 for then withhold the mark in 2(i))	**1**
1	(iii)	method and result:	R_1 to mm or to 0.1 mm, in range 62(.0) mm to 92(.0) mm **or 0/2** ✓✓ (reject 1 sf answers) correct substitution of T_1 and r, no mixed units or deduct 1 mark; if no unit is found in the working and/or answer for R_1 and for R_2 for then withhold the mark in 2(ii)	**2**
1	(iv)	method and explanation:	extrapolate [extend] line and read [find] the horizontal [r] intercept $_1$✓ (bland 'find intercept' is not enough) (from $T_1 = 2\pi\sqrt{\frac{7(R_1 - r)}{5g}}$) deduces that when $T_1^2[T_1] = 0$, $(R_1 - r) = 0$ $_{23}$✓✓ [for poor/missing analysis, statement that R_1 = horizontal [r] intercept earns $_3$✓only] or extrapolate [extend] line and read [find] the vertical [T_1^2] intercept $_1$✓ (from $T_1^2 = \frac{-28\pi^2 r}{5g} + \frac{28\pi^2 R_1}{5g}$) deduces that when $r = 0$, vertical [T_1^2] intercept $= \frac{28\pi^2 R_1}{5g}$ $_2$✓ explains rearrangement ie $R_1 = \frac{5g}{28\pi^2} \times \text{vertical intercept}$ (ie reject bland 'rearrange to find R_1') [(measure gradient of graph, then) $R_1 = \frac{\text{vertical intercept}}{\text{(-)gradient}}$] $_3$✓ (condone $\frac{5g}{28\pi^2} \approx \frac{7}{4\pi^2} \approx \frac{5}{28}$) [the idea that reading T_1 and the corresponding value of r from a point on the line, then using the equation, rearranged to find R_1 is worth 1 MAX]	**3**
			Total	**8**

Question 2				
2	(i)	method:	T_2, result sensible, eg about 2.0 s, from nT_2, where n or $\Sigma n \geq 10$; nT_2 to 0.1 s or 0.01 s ✓	**1**
2	(ii)	result:	R_2 in range 62(.0) mm to 92(.0) mm ✓(reject 1 sf answers)	**1**
2	(iii)	sketch:	fiducial mark shown at centre of oscillation **or 0/2**, some part (or all) of the mark must be beyond free end of ruler ✓ (tolerate mark shown aligned with top or bottom surface of the ruler providing the ruler is horizontal) eg 	**2**
		explanation:	this is where ruler is moving fastest [transit time is least] ✓ (condone for fiducial mark not beyond end of ruler but at the centre of oscillation)	
2	(iv)	method and result:	uncertainty in $20T_2$ = 0.5 × (41.4 – 38.7) = 1.35 (s) (reject 1.4 (s)) mean $20T_2$ = 40.26 (s) [40.3 (s)] $_1$✓ percentage uncertainty = $100 \times \frac{1.35}{40.26} = 3.35(\%)$ $_2$✓ (expect same answer if 40.3 used; accept 3.353(%), 3.47(%) if 1.4 and 40.3 are used, 3.23(%) if all 3sf data used; reject any 2 sf)	**2**
			[if T_2 values are calculated from $20T_2$: uncertainty in T_2 = 0.5 × (2.07 – 1.935) = 0.0675 (s) (reject 0.068 (s)); accept 0.065 (s) if 1.94 used; mean T_2 = 2.01(3) (s) $_1$✓ percentage uncertainty = $100 \times \frac{0.0675}{2.013} = 3.35(\%)$ etc $_2$✓]	

2	(v)	explanation:	plausible reasons why results are different, any 2 from valid reason why R_1 and R_2 are different ie due to the thickness of mirror, so $R_2 = R_1 + t$ ${}_1$✓ (reject 'R_1 is concave and R_2 is convex') equation giving R_2 is only an approximation ${}_2$✓ uncertainty in T_1 is large because the motion dies away quickly [cannot time many oscillations] or motion tends to become elliptical [ball does not travel in a straight line] ${}_3$✓ uncertainty in T_2 is large because the ruler passes the fiducial mark slowly or the ruler tends to rotate on upturned mirror, changing the plane of oscillation ${}_4$✓ ball bearing may slide rather than roll ${}_5$✓ period of ball bearing is not constant since (as it rolls) it subtends a large angle (hence not true shm) ${}_6$✓ period of ruler is not constant since point of contact with mirror changes (hence not true shm) ${}_7$✓ (for ${}_6$✓ or ${}_7$✓ reject ideas about damping affecting the period and reject idea that mirror may not be perfectly spherical or that it distorts under the weight of ball or ruler; give no credit for short/long periods as difficulties and reject unqualified statement that 'random errors are different')	**2 MAX**
			Total	**8**

Section A, Part 2

Question 1				
1	(a)	accuracy:	final answer for T_0 in range 15.0(0) s to 30.0(0) s ✓ (reject ≥ 5 sf) raw reading(s) must be to 0.1 s or to 0.01 s and to the <u>same precision</u> as for readings of T or deduct sf mark in (b); if T_0 is not found from repeated readings, deduct 1 result mark in (b)	1
1	(b)	tabulation:	R /Ω T /s ✓	1
		results:	6 sets of R and T ✓✓ deduct 1 mark for each set missing; deduct 1 mark for any T or T_0 not found from repeated readings	2
		significant figures:	all (raw) T and T_0 to nearest 0.1 s or to nearest 0.01 s ✓	1
1	(c)	tabulation:	$\dfrac{R}{R+R_0}$ (reject $R/R + R_0$)/ (no unit) T /(s) ✓	1
		significant figures:	all 6 sets of $\dfrac{R}{R+R_0}$ correctly calculated (see right), all sets to 2 sf or all to 3 sf (tolerate all to 4 sf) ✓ if ($\dfrac{R}{R+R_0}$ = 1, T_0) is tabulated this must be plotted too 0.828 0.83 0.682 0.68 0.548 0.55 0.411 0.41 0.282 0.28 0.128 0.13	1

1	(d)	axes:	marked $\frac{R}{R+R_0}$ (vertical) and *T*/s (horizontal) ✓✓ deduct ½ for each error involving label, separator or unit, 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 ✓ and half the grid vertically ✓ (if necessary a false origin, correctly marked, should be used to meet these criteria; either or both marks may be lost for use of a difficult or non-linear scale)	**2**
		points:	6 points plotted correctly (check at least three including any anomalous points) ✓✓✓ 1 mark is deducted for every point missing or false and for every point > 1 mm from correct position deduct 1 mark if any point is poorly marked; no credit for false data	**3**
		line:	ruled best fit straight line of positive gradient ✓ maximum acceptable deviation from best fit line is 2 mm, adjust criteria if graph is poorly scaled; withhold mark if line is poorly marked, no credit for false data	**1**
		quality:	(all) **6 points** to $\pm$ 2 mm of a straight line of positive gradient (judge from graph, providing this is suitably-scaled) ✓	**1**
			Total	**16**

Section B

Question 1			
1	(a)(i)	valid attempt at gradient calculation or 0/2 correct transfer of *y*- and *x*-step data between graph and calculation or 0/2 ✓ (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] (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)	GT_0, no unit, in range 1.24 to 1.30 ✓✓ [1.19 to 1.35 or 1.3 ✓]	**2**
1	(b)(i)	(when the time for the voltmeter reading to fall by 50% = T_0 there is nothing connected between P and Q, hence) $R = \infty$ ✓	**1**
	(b)(ii)	(when $T = T_0$, $R = \infty$) $\frac{R}{R+R_0} = 1$ ✓ (don't insist on correct supporting argument since this result can be inferred from the graph; don't insist on detail such as 'extrapolate' and/or 'read off')	**1**
		Total	**6**

Question 2			
2	(a)(i)	there are 4 voltmeter readings [values/samples/steps] recorded during each 2 second interval [two voltmeter readings recorded per second etc] ✓	**1**
2	(a)(ii)	(idea that) the required voltmeter reading(s) may not be shown, ie the pd across the capacitor reaches the required reading between samples $_1$✓ if required value of *V* is not displayed the correct *T* could occur at any point during a 0.5 s interval [*V* is unlikely to be exactly 50% at the instant the sample is taken] $_2$✓ values shown on the voltmeter are not bound to be in the ratio of 2 to 1 $_3$✓ true value of *V* is changing while voltmeter reading is not changing $_4$✓ (reject bland ‘sample rate is too low’ or ‘can’t get accurate *V*’; reject ideas such as the ‘voltmeter readings are discrete values’, ‘readings change quickly’ or ‘reading voltmeter and stopwatch at the same time is difficult’; reject idea that at the time a sample is taken there are different possible values of *V*)	**MAX 1**
		Figure 6 shows that the voltmeter never reads 2.5 (V) ✓ (this also earns $_1$✓) [*T* could be anywhere between 5.5 (s) and 6.0 (s) ✓ (this also earns $_2$✓)]	**1**
2	(a)(iii)	(idea that) student is measuring 2*T* [student should divide measured time by 2 to find *T*] ✓	**1**
		timing interval is longer [doubled] so percentage [fractional] uncertainty (due to human or random error) is smaller [halved]; accept ‘uncertainty in calculated value of *T* is halved’ ✓ rate of change of *V* is less after 2*T* [(vertical steps) are smaller] so more likely to see the required value of [closer to] the required voltmeter reading ✓ (reject ‘human error is reduced’ or ‘uncertainty is halved’; reject the idea that uncertainty is reduced because ‘the number of samples have been doubled’ or the idea that the precision of the voltmeter readings improves / *V* is more accurate’ when the reading is changing more slowly)	**MAX 1**
2	(a)(iv)	(idea that) the sample rate [readings taken per second] (of the data logger) is (much) higher (than that of the voltmeter [2 Hz]); allow ‘takes readings more rapidly’ ✓ (any suggestion that the data logger takes ‘continuous readings’ or ‘takes more readings’ loses the mark; reject idea that the sensor has a sample rate)	**1**
2	(b)(i)	systematic (error); accept ‘zero error’ ✓	**1**
2	(b)(ii)	either **no** because own graph was straight line **or yes** because own graph showed increasing gradient ✓ (the answer is for the explanation and must refer to the **shape** of the candidate’s **own graph**)	**1**
		Total	**8**

Question 3			
3	(i)	precision = 0.005 mm [5 μm] ✓ (suitable unit essential)	**1**
3	(ii)	$R = 84.4 \times \left(\frac{100 - 4.5}{100}\right) = [84.4 \times 0.955] =$ $\underline{80.6}$ (mm) ✓ (reject 80.8 (mm))	**1**
3	(iii)	percentage uncertainty in R = 2 × percentage uncertainty in T ∴ percentage uncertainty in T = 2.25(%) [2.3(%)] ✓	**1**
3	(iv)	uncertainty in T = $\frac{2.25 \times 2.04}{100} = 0.0459$ (s) uncertainty in 10T = 0.459 (s) [0.46 (s)] ✓ (2.3% will lead to 0.47 (s); allow ecf from (iii), reject 0.5 s)	**1**
		Total	**4**

Question 4			
4	(a)	2 <u>smooth</u> curves to show envelope of exponential decay waveform; lines to be continuous from first to fifth points, maximum deviation from best-fit lines thorough each set of 5 points must not be greater than 1 mm ✓	**1**
		equilibrium position marked on grid with horizontal line at A = 15.7 ± 0.1 cm ✓	**1**
4	**(b)**	evidence of **valid** working (using the line(s) and/or the equilibrium position) established in (a)(iii) to **test for** the exponential nature of the decay (working may be shown on the graph): do not penalise confusion between n and time either evidence of relevant A values [2A ie A–(–A)] measured from graph (correct to nearest mm) or deduced from difference between tabulated values and equilibrium position of pointer) **or 0/3** $_1$✓ <u>at least</u> two half life measurements (expect evidence of working) $_2$✓ values obtained giving $n_{1/2}$ = 6.3 ± 0.3 from **either or both** curves **confirming exponential decay** $_3$✓ or $_1$✓ as above; evaluates <u>at least</u> two ratios of successive amplitudes [or the fractional change in successive amplitudes], eg $\frac{A_0}{A_1}$ and $\frac{A_1}{A_2}$ $\left[\frac{A_0 - A_1}{A_0}\text{ and }\frac{A_1 - A_2}{A_1}\right]$ $_2$✓; ratios obtained giving consistent results to ± 5% **confirming exponential decay** $_3$✓ or $_1$✓ as above; evaluates difference between natural logs of <u>at least</u> two successive amplitudes, eg $\ln(A_0) - \ln(A_1)$ and $\ln(A_1) - \ln(A_2)$ ✓ differences obtained giving results consistent to ± 10% **confirming exponential decay** $_3$✓	**3**
		Total	**5**