Version 1.0

General Certificate of Education (A-level)
June 2012

Physics PHA6/B6/X

Unit 6: Investigative and practical skills in A2 Physics

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this Mark Scheme are available from: aqa.org.uk

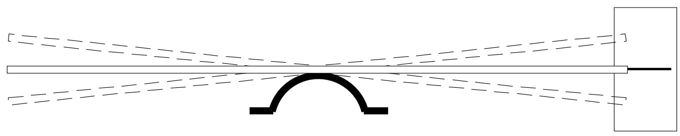
Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX.

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 <u>diameter</u> 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 <u>to mm or to 0.1 mm</u>, 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:	<u>extrapolate [extend] line</u> 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 <u>extrapolate [extend] line</u> 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 $= \frac{28\pi^2 R_1}{5g}$ $_2$✓ <u>explains</u> 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 <u>on the line</u>, 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) [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**

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); ifT_0 is not found from repeated readings, deduct 1 result mark in (b)	**1**
1	(b)	tabulation:	R /□ 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:	$\frac{R}{R+R_0}$ (reject $R/R + R_0$)/ (no unit) T /(s) ✓	**1**
		significant figures:	all 6 sets of $\frac{R}{R+R_0}$ correctly calculated (see right), all sets to 2 sf or all to 3 sf (tolerate all to 4 sf) ✓ if ($\frac{R}{R+R_0} = 1$, 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 ✓ <u>and</u> 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 <u>+</u> 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 □m] ✓ (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**

UMS conversion calculator www.aqa.org.uk/umsconversion