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General Certificate of Education
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Physics PHA6/B6/X

Investigative and Practical Skills in A2 Physics

Unit 6

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 meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting 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 the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

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

Section A, Task 1

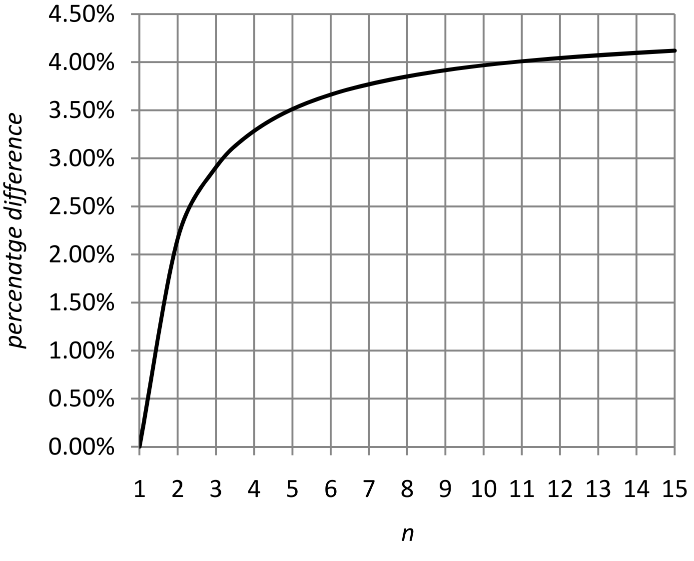
Question 1			
(a)	accuracy	$T_3 > T_2 > T_1$, values sensible ✓ (any) T from pT where $\Sigma p \geq 20$ ✓ $p)T_1$, $(p)T_2$ and $(p)T_3$ recorded consistently to 0.1 s or to 0.01 s ✓ [$T = \frac{T}{2}$ can earn $_{23}$✓✓; $T = nT$ or $T = \frac{1}{T}$ can earn only $_3$✓; n in fixed time can earn $_1$✓ only]	**3**
(b)	method	log T and corresponding log n values correctly calculated for **all three** of T_3, T_2 and T_1 (tolerate log 10T, ln T **and** ln n) $_1$✓ all (of each set of log values) recorded to 3 or to 4 dp $_2$✓ [if ln values tabulated accept all to 3 sf or all to 4 sf] plots graph of log n (↑) against log T (→) [or vice-versa] and calculates gradient $_3$✓ points to occupy ½ grid each way; Δ should occupy ½ grid each way $_4$✓ [at least 2 $\frac{\Delta \log n}{\Delta \log\,(T/s)}$ evaluated $_{34}$✓✓; any $\frac{\Delta \log n}{\Delta \log\,(T/s)}$ $_{34}$✓]	**max 3**
	result	valid working to show $x = 2$ (integer value only) ✓ [at least 2 n/T^2 confirming $x = 2$ ✓] (ecf allowed for $T = nT$; this can get 4 marks)	**1**
	method/ result	[guesses that $x = 2$: calculates T^2 values and plot a graph of T^2 against n; points to occupy ½ grid each way $_{1234}$✓; straight line graph **through the origin** (confirming $x = 2$) ✓ = 2/4 max]	
(c)	method	measures directly or calculates length, l, of (any) paper clip chain; substitutes value into $2\pi\sqrt{\frac{l}{g}}$ to correctly find period of simple pendulum of length l $_1$✓, or $_2$✓ = 0 compares result with relevant measurement of T and shows these to be inconsistent $_2$✓ [measures directly or calculates length, l, of (any) paper clip chain; substitutes T into $\frac{T^2 g}{4\pi^2}$ to correctly find length of simple pendulum of period T $_1$✓ or $_2$✓ = 0; compares result with relevant measurement of l and shows these to be inconsistent $_2$✓] [measures directly or calculates length, l, of (any) paper clip chain; evaluates $\frac{T^2}{l}$ for paper clip pendulum $_1$✓ [reads off intercept on log n axis; evaluates k from ($10^{\text{intercept}}$) then calculates ($k \times c$)]; compares result with $\frac{4\pi^2}{g}$ [4.02 s^2m^{-1}] and shows these to be inconsistent $_2$✓]	**2**
		Total	**9**

Question 2			
(a)	accuracy	time, τ, for energy transfer with 4 paper clips attached, to SV ± 20% ✓ (penalise here, but not in (b) for $\tau = \frac{\tau}{2}$)	**1**
(b) (i)/(ii)	accuracy	τ with 5 paper clips, result less than τ with 4 paper clips; τ with 6 paper clips, result less than τ with 5 paper clips ✓	**1**
(a)/(b)	method	any τ from repeated readings; raw readings consistently recorded to 0.1 s or 0.01 s ✓	**1**
(b) (iii)	explanation	**three correct** calculations of $\tau \times$ number of paper clips [or inverse of ($\tau \times$ number of paper clips)] $_1$✓ valid comment about result of **relevant** calculation; accept statement that inverse proportion is proven if all results for ($\tau \times$ number of paper clips) ≤ 5 % of the mean and not proven if any result ≥ 10 % of the mean; accept either response if any result lies between 5% and 10% of the mean $_2$✓ [other approaches: $\frac{\tau_a}{\tau_b}$ compared with $\frac{b}{a}$ and $\frac{\tau_a}{\tau_c}$ with $\frac{c}{a}$, **or** compared with $\frac{\tau_b}{\tau_c}$ with $\frac{c}{b}$, $_1$✓; valid comment $_2$✓] [correct use of 2 sets of data and valid comment is worth $_{12}$✓]	**2**
(c)	method	(τ very long, hence) difficult to determine when pendulum has come to rest [reached zero/maximum amplitude] (and hence, when to start/stop the watch) ✓ reject 'time consuming' argument or statement that 'it is hard to tell when the displacement is zero/maximum')	**1**
		Total	**6**

Section A Task 2

Question 1			
(a)	accuracy	*nc* recorded to mm and sensible, *n* (or Σ*n*) ≥ 10; *c* calculated (and sensible, eg about 5 cm), result given to 3 sf or 4 sf ✓	**1**
(b)	accuracy	*d* found from average of at least 3 (sensible, eg about 1 mm) repeated readings; raw readings of *d* to 0.01 mm, final answer given to 3 sf or 4 sf ✓	**1**
(c)	tabulation	*x* /mm *y* /mm ✓ any missing label or separator loses the mark	**1**
	results	at least 10 sets of *x* and *y* (expect 12 or 13) ✓ *x* = 0 data set shown in table ✓ largest *x* value in range 355 mm to 380 mm ✓ (9/8 sets = 2 max, 7/6 sets = 1 max; ignore any details of junction/clip number in the tabulation; no credit for false/displaced data, or sets on the wrong side of catenary)	**3**
	significant figures	all *x* and all *y* to nearest mm ✓	**1**
	quality	at least 10 points to ± 2mm of a smooth curve of continuously increasing, (positive) gradient (judge from graph; adjust criterion if graph is poorly-scaled) ✓ (do not penalise for graph showing the wrong/both sides of the catenary or for displaced data)	**1**
(d)	axes	marked *y*/mm (vertical) and *x*/mm (horizontal) ✓✓ deduct ½ for each missing label or separator, rounding down [bald *y* (vertical) and *x* (horizontal) ✓] deduct a mark if the interval between the numerical values is marked on either axis with a frequency of > 5 cm	**2**
	scales	points should cover at least half the grid horizontally ✓ **and** half the grid vertically (do not penalise false data) ✓ (if necessary, a false origin should be used to meet these criteria; either or both marks may be lost for use of a difficult or non-linear scale; be lenient with displaced data or if the graph shows the wrong side or both sides of the catenary)	**2**
	points	all tabulated points plotted correctly, minimum of 10 points (check at least three including every anomalous point) ✓✓✓ 1 mark is deducted for every tabulated point not plotted, for every point > 1 mm from correct position and if any point is poorly marked; 9/8 points = 2 max, 7/6 points = 1 max no credit for false/displaced data, or sets on the wrong side of the catenary	**3**
	line	best fit line of positive, continuously increasing gradient ✓ maximum acceptable deviation from best fit line is 2 mm (adjust criterion if graph is poorly-scaled); any point of inflexion loses this mark (tolerate no more than one straight link between adjacent points); there is no credit for false data but be lenient with displaced data or if the graph shows the wrong side or both sides of the catenary)	**1**
		Total	**16**

Section B

Question 1		
(a)	*n* = 24 correctly substituted; results for *c* and *d* correctly substituted (watch for mixed units) ✓ *L* to mm (4 sf) or to cm (3 sf), to supervisor's value ± 50 mm (± 5 cm) (no ecf for false data) ✓	**2**
(b) (i)	percentage difference = 100 × $\left(\frac{2d}{c} - \frac{2d}{nc}\right)$ ✓✓ **or** any **two** of the following points: as *n* increases, 2*d*(*n* – 1) increases ✓ as *n* increases, the **difference** between ***L* and *nc*** increases ✓ as *n* increases, 2*d*(*n* – 1) is a bigger proportion of *L* ✓ percentage difference = $\frac{2d(n-1)}{L}$ ✓	
(b) (ii)	the increase [change / difference] in percentage difference becomes smaller as *n* increases ✓ (accept use of data from Table 1 to illustrate answer)	
(b) (iii)	sketch showing graph (accept axes either way round) of percentage difference against *n* [tolerate log *n*], eg as below ✓  read off along *n* axis where percentage difference = 4% (can be shown on sketch; (ecf if sketch shows wrong trend) ✓ **round down** to the nearest (integer) value of *n* ✓ use larger scale [false origin] to reduce uncertainty in *n* ✓ (reject: 'read off more points around *% difference* = 4 %') [alternative method which can earn up to 3 marks: **calculate** percentage difference for values of *n* between 16 and 8 (accept values of *n* < 16 or values of *n* > 8) ✓ calculate percentage difference using $\frac{2d(n-1)}{L}$ ✓ required value of *n* is when percentage difference has largest value < 4% ✓]	**max 5**
	Total	**7**

Question 2		
(a)	method: evidence that a tangent, or a line parallel to the tangent, or a normal or a chord has been drawn at the curve where x = 243, y = 260, ie at 7th point (accept any as hypotenuse of Δ); y-step at least 8 cm and x-step at least 8 cm [minimum x-step and minimum y-step = 270 mm] ✓ correct transfer of y-step and x-step data between graph and calculation ✓ (mark is withheld if points used to determine either step > 1 mm from correct position on grid) result must be min 2 sf, max 4 sf; ignore any unit given in error but do not allow ecf in (b) (i) and (c) (there is no credit for gradient calculations based on incorrect methods, eg $G = \Delta x/\Delta y$ or $G = \tan\theta$; in such cases there is no ecf to 1 (b))	**2**
(b) (i)/(ii)	p 3 sf or 4 sf, correct substitution (allow ecf), answer with suitable unit; q 3 sf or 4 sf, correct substitution (allow ecf), answer with no unit ✓	**1**
(c)	r in range 366 mm to 448 mm (accept 4 sf) or 2 sf answer between 0.38 m to 0.44 m ✓✓ [305 mm to 365 mm or 449 mm to 509 mm or 2 sf between 0.31 m to 0.37 m or 0.45 m to 0.50 m ✓] (do not penalise for missing unit if also missed for p)	**2**
	Total	**5**

Question 3		
(i)	sketch showing fiducial mark positioned **at the centre of oscillation** of the chain (or 0/2); some part of the mark should be below ¾ length of the chain, and ideally be positioned below end of chain ✓ (accept perspective sketch)	**1**
(ii)	(at centre of oscillation) because this is where the transit time is least [speed of chain is greatest] ✓	**1**
	Total	**2**

Question 4		
Table 2	see table below	
(a)	mean τ/s values correct to 0.1 s; reject > 1 dp ✓	**1**
(b) (i)	uncertainty from 0.5 × range, values correct, either all to 3 sf or all to 2 sf ✓ (no ecf from (a))	**1**
(b) (ii)	percentage uncertainty from 100 × $\Delta T/T$, result to same sf as in (b) (i) ✓ [any two correct rows showing consistency in sf for cols 3 & 4 earns 1 mark]	**1**
(c) (i)	τ = 62(.0) ± 1 s ✓	**1**
(c) (ii)	*period* to 0.01 s in range 1.67 to 1.77 s (reject 1.7 s) ✓ or 0/2 from n × period where $\Sigma n \geq 20$ ✓ (reject cycles in a fixed time)	**2**
(d)	***statement of advantage*** (*eg elimination of human error*) *and* ***explanation*** (eg *better precision*) *earns 2 marks – full credit can be gained for two linked answers: 1 mark can be earned for statement without explanation, but* ***not vice-versa****; only 2 marks max for each response* ***statement*** do not have to release the bob and start timing at same moment [or other valid example associated with overcoming systematic error] ✓ (no credit for 'avoid parallax error') ***explanation*** τ is measured with greater **accuracy** (reject 'more reliable') ✓ ***statement*** no **human**/**random**/**reaction error** is involved in the timing process ✓ and/or it is easier to ascertain the moment/point of maximum [minimum] amplitude ✓ and/or samples can be taken at very high frequency/greater **sensitivity** obtained using digital sensors (allow 'can record to more decimal places; reject 'can take more data' and 'measure over short intervals of time') ✓ and/or can collect data for many cycles of energy transfer [over longer time] (hence can calculate a more reliable mean) ✓ ***explanation*** τ is measured with greater **precision** (allow 'more **reliably**') ***statement*** the experiment does not require the experimenter's constant attention (reject 'data logger is automatic' idea)/the information can be analysed or manipulated later/can scroll through the data line by line ✓ and/or the data is easily (transferred to a spreadsheet to be) graphed [can draw the envelope around the displacement – time graph to determine τ] ✓ ***explanation*** data logging is **convenient** (allow 'labour/time saving') ✓ (while giving credit for any valid improvement, do not credit the claim that this leads to better accuracy *and* better precision)	**4 max**
	Total	**10**

Table 2

n	mean τ/s	uncertainty/s	percentage uncertainty
3	113.5	2.30 [2.3]	2.03% [2.0%]
5	66.9	2.85 [2.9]	4.26% [4.3%]
7	47.6	2.15 [2.2]	4.51% or 4.52% [4.6%]