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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				
a i/ii	method/ accuracy	A_{10}, A_{20} and A_{30} recorded to nearest mm, at least three sets **for each**; means to 1 mm or 0.1 mm, (correctly) calculated ✓		**1**
a iii	method	ΔA_{10} to 1 mm or 0.1 mm, from half of the range of A_{10} ✓		**1**
b	method	(correct transfer of mean values of A_0, A_{10}, A_{20} leading to) three $\frac{A_n}{A_{n+10}}$ ratios calculated (or 0/2), result all to 3 sf or all to 4 sf only ✓		**1**
	conclusion	clear statement about teacher's suggestion, (eg 'confirmed since $\frac{A_n}{A_{n+10}}$ ≈ constant' or similar) supported by evidence from **three** valid calculations (allow for 2 sf ratios) ✓ must reject theory if largest ratio ÷ smallest ratio > 1.12, must accept theory if largest ratio ÷ smallest ratio < 1.06, (can accept or reject or state undecided if between 1.06 and 1.12) [if a discernable trend can be identified in the ratios then accept this as grounds for **rejecting** the theory]		**1**
c	explanation	**any two** of the following, each with some amplification [2 valid difficulties without amplification = 1 max] **random** variation due to contact: golf ball does not always rebound normally off the vertical face of the brick [transient vibration occurs in pendulum after impact] $_1$✓ ('hard to keep ball parallel to ruler' or 'difficult to ensure initial displaced position of ball is consistent') **position** of observer: it is difficult to avoid parallax error in aligning the eye with the scale of the ruler [the string gets in the way, significant distance between ball and ruler] $_2$✓ **making observations**: duration of the swing is very short so observer **must move** position (after releasing ball) to record rebound amplitude $_3$✓ (reject arguments that the (increasingly) short time between contacts makes is difficult to measure and record successive amplitudes, or that it is difficult to judge when the ball is at rest or that the ball is stationary/at maximum amplitude for a **short** time) **quality of data**: the amplitude decays quickly so (values quickly become very small) so there is large **percentage** uncertainty when *n* is large $_4$✓ (reject 'amplitude becomes similar') ✓ **quantity of data**: the amplitude decays quickly so maximum *n* is small $_5$✓		**2**
			Total	**6**

Question 2				
a	i/ii	results	V_0 recorded with unit and further values of V, all to 3 sf or all to 4 sf, to complete the table; values sensible ✓	**1**
b		scale/points	vertical scale to cover at least half the grid vertically, with appropriate intervals; all 18 points plotted correctly (check one from each column in table) ✓	**1**
		line/quality	smooth continuous curve drawn; reasonable approximation of 2 full cycles of a sine wave, withhold mark if amplitude variation > 1 cm or if there are less than 12 points to 2 mm of the best-fit line ✓	**1**
c	i/ii	deduction	(largest values of) V_{max} and V_{min} correct from graph to nearest mm and recorded to an appropriate precision; A from ½×(V_{max} – V_{min}) ✓ (do not penalise here for missing or wrong units with V_{max}, V_{min} and A if already penalised in (a)(i); if no line drawn examiner should add smooth curve at maxima and minima of trend)	**1**
c	iii	method	suitable value of θ identified; take candidate's value and award mark if adjacent peak [trough] is 45 ± 5° of value (no credit if a range of values is given) ✓ since (sensitivity is greatest where) $\frac{dV}{d\theta}$ [gradient/**rate** of change of V] is large**st** (accept 'line/wave is steep**est**', reject 'very steep', reject 'large') ✓	**2**
d	i	explanation	readings of V are **reduced** ✓ since the aperture is smaller [**less** light is incident on the solar cell/card blocks some of the light] ✓ (reject 'filter blocks some of the light')	**2**
d	ii	explanation	suitable **procedure** identified, eg check the scale readings at each end of the marked diameter; the difference between these readings must add up to 180° [(keep θ the same) and adjust the card until the voltmeter reading is a maximum] ✓ [ensure (eg by measuring gap) that perimeter of card **remains aligned** with the circle marked on the circular scale or that the gap between the card and the scale **is the same** (all the way around) ✓] (reject 'repeat readings and average', 'look through the filter to ensure that none of the circular scale is visible'/'keep two circle in line' or ideas about changing the physical arrangement, eg 'change the diameter of the card to match the scale'/'mark the outline of the card on the scale' unless 'and 'check the card stays aligned with the outline' [so card remains in correct position'] is added)	**1**
			Total	**9**

Section A, Part 2

Question 1			
a	accuracy	V_0, between 300 and 450 mV ✓ (adjust if problems reported)	**1**
b/c	tabulation	Q /ml V /mV ln(V/mV) ✓✓ deduct ½ for each missing or wrongly-connected label, deduct ½ for each missing separator, rounding down; tolerate cm^3 for ml; accept ln(V) and do not penalise here for ln(V)/mV but reject log(V)	**2**
b	results	at least 5 values of V for $Q \leq 200$ ml; must include initial (non zero) Q in range 90 to 100 ml ✓ at least 5 values of V for $Q > 200$ ml, largest of these values must be ≥ 475 ml ✓	**2**
	significant figures	all (raw) V to nearest mV but be tolerant of auto-ranging meters, in which case all should be to 3 or 4 sf (do not tolerate all trailing zeros, eg 11.0, 3.00) ✓	**1**
b/c	quality	to be based **only** on Q values between 90 ml and 250 ml ✓ at least 5 points to 2 mm of the best straight line of negative gradient through these points (this may not be candidate's line; adjust criteria if graph is not suitably-scaled)	**1**
c	significant figures	all ln(V/mV) correct; if most significant figure is same for all data then all values must be shown to 3 dp or 4 dp ✓ [if msf varies then tolerate all to 3 sf or all to 4 sf; do not penalise if msf = 0]	**1**
	axes	marked ln(V/mV) (vertical) and Q/ ml (horizontal) ✓✓ [bald ln(V) (vertical) and Q (horizontal) ✓] withhold axis mark 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; vertical scale should accommodate Q = 0, ln(V_0) if this is tabulated ✓ (a false origin should be used on the vertical scale to meet these criteria; either or both marks may be lost for use of a difficult or non-linear scale)	**2**
	points	all tabulated points to be plotted correctly (check at least three, including any anomalous points) ✓✓✓ 1 mark is deducted for every tabulated point (including Q = 0, ln(V_0), if tabulated) missing from the graph every point > 1 mm from correct position any point poorly marked; no credit for false data, eg ln(V/V) or $\log_{10}$(V)	**3**
	line	**straight** (ruled) best fit line of negative gradient; no credit if line is poorly marked ✓ judge line on region where the trend in the plotted points is negative; consider points in this region that are further than 2 mm from the line and if the number of these above the line is different by more than 3 to the number below, then withhold the mark	**1**
		Total	**16**

Section B

Question 1			
a	i	valid attempt at gradient calculation and correct transfer of data **or** $_{12}$✓**= 0** (if a curve is drawn in error a tangent should be drawn to form the hypotenuse of the triangle) correct transfer of *y*- and *x*-step data 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 $_2$✓ [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**
a	i/ii	*G* to 3 sf and **negative**; ignore any unit given vertical intercept, 3 or 4 sf, **no unit**, (reject ln(*V*/mV) as unit), read correctly to the nearest mm or found by valid calculation if a false origin has been used ✓ (accept $\ln(V_0)$ as intercept if this is justified)	**1**
b	i	**description** that graph should have a **constant negative** gradient [straight line, negative gradient] (accept sketch) ✓ (needs more than a comparison of $y = mx + c$ and $\ln(V) = -\lambda Q + \ln(V_0)$) $G = -\lambda$ [$-G = \lambda$] (accept λ = magnitude/size of the gradient) ✓ vertical intercept = ln(*P*) [$P = e^{(\text{vertical intercept})}$] ✓	**3**
b	ii	**either** analogy is rejected or given only qualified confirmation; suitable **qualitative** comments are: only a small part of graph is linear/straight [line is not linear/straight, a curve (accept parabola), or value/sign of gradient changes] ✓ the vertical intercept is not where $\ln(V_0)$ is plotted ✓ suitable **quantitative** observations are: quotes **value** of *Q* after which graph is not linear/straight [quotes **range** of *Q* values for which graph is linear/straight or number of points that fit linear region] ✓ quotes vertical intercept value and states this is $\neq \ln(V_0)$ [$e^{(\text{vertical intercept})} \neq V_0$] ✓ correctly applies $\ln(V) = -\lambda Q + \ln(V_0)$ to predict *V* [ln(*V*)] for a certain value of *Q*, using the result for λ and the measurement of V_0 [$\ln(V_0)$] made in Sec A Part 2(a)(i); shows prediction to be incompatible with *V* from graph] ✓ **or** if justified by evidence from graph, ie at least half of plotted points illustrating trend, analogy is confirmed; suitable **qualitative** comments are graph is **linear** [line is **straight** or gradient = **constant**] (do not insist on 'negative gradient') ✓ the vertical intercept is (close to) where $\ln(V_0)$ is plotted ✓ suitable **quantitative** observations are: states the **number** or **fraction** of plotted points fitting the trend line ✓ quotes vertical intercept value and states this is $\approx \ln(V_0)$ [$e^{(\text{vertical intercept})} \approx V_0$] ✓ correctly applies $\ln(V) = -\lambda Q + \ln(V_0)$ to predict *V* [ln(*V*)] for a certain value of *Q*, using the result for λ and the measurement of V_0 [$\ln(V_0)$] made in Sec A Part 2(a)(i); shows prediction to be (roughly) compatible with *V* from graph] ✓	**max 3**
		Total	**9**

Question 2		
a i	difficult to read (the graduations on the) measuring cylinder against background of dark-coloured liquid or difficult to see **the position of the meniscus** (reject bland 'hard to see meniscus') [meniscus was not at continuous level/ink had wetted the inside of measuring cylinder] or any other reasonable comment, eg effect of bubbles at the surface (reject comments about precision or idea that some residual ink is left in the measuring cylinder) ✓	**1**
a ii	read volume of ink solution by reading position of the **bottom** of the meniscus against the scale (accept evidence of sketch) ✓ view at eye level (accept sketch) to avoid/reduce **parallax** error ✓ place measuring cylinder on a level surface (tolerate 'bench') before making measurement ✓	**max 1**
b i	(idea that) readings made (when *Q* small) by student A lack **precision** [intervals between *V* readings are (initially) large] (allow 'harder to get ink at level of graduations on measuring cylinder') ✓ [to transfer ink in the small increments when *Q* < 200 ml, the (percentage) uncertainty [error] in *Q* is greater for student A]	**1**
b ii	(idea that) student B has to make **more** (accept 2) readings [experiment takes a long time to complete/is time-consuming] ✓ (reject 'the measuring cylinder is not big enough to transfer (40 to 70 ml) of ink') [to transfer ink in larger increments when *Q* > 200 ml the cylinder has to be used **more than once** for student B]	**1**
	Total	**4**

Question 3		
a	λ [the gradient] = (–) 0.015 $\left[(-)\frac{0.3}{20}\text{ or similar}\right]$ ✓ $N_{½}$ from (–) $\frac{ln}{\lambda}\left[(-)\frac{ln2}{0.015}\right]$ ✓ 46.2(1) slides (accept 46 but do not penalise '47 slides needed to halve *V*') ✓ [λ = 0.015 or use of ratio $\frac{0.3}{20}$ ✓ determination of V_0 = 424(.1) mV; ln(V_0/2) = 5.36 [5.357] ✓ $\frac{6.05-5.36}{0.015}$ = 46(.0) slides (accept 46.2,'47 slides needed to halve *V*' etc) ✓]	**3**
b i	(student must measure or calculate) thickness of slide, *t*; half-value thickness = $N_{½}$ × *t* [= result from 3(a) × *t*] ✓	**1**
b ii	procedure: measure the thickness of multiple slides (either singly or in a stack) and calculate average thickness [divide by number of slides] ✓ (reject bland 'repeat and average') [measure the thickness at **different points** on the slide, and **average** by number of readings or measure the thickness of different slides and average]	**1**

b	iii	procedure: **close** jaws and check reading (= zero) ['check for **zero error**'] ✓ (reject idea of measuring 'known' dimension and checking reading or that micrometer is 'zeroed/'set to zero'/'zero calibrated' before use')	**1**
		Total	**6**

Question 4			
a		*t* from $\frac{(R_2 - R_0)}{12}$ = 1.19 **mm** (3 sf only) ✓	**1**
b		$n = \frac{14.28}{9.71}$ = 1.47, no unit (3 sf preferred but tolerate 4 sf, do not penalise here and in part a for sf) ✓	**1**
c	i/ii	$\Delta\,(R_2 - R_0) = \Delta(R_2 - R_1)$ = 0.08 **mm** ✓	**1**
c	iii	P_{2-0} = % uncertainty in $(R_2 - R_0) = 100 \times \frac{0.08}{14.28}$ = 0.56(0)% [0.6%] and P_{2-1} = % uncertainty in $(R_2 - R_1) = 100 \times \frac{0.08}{9.71}$ = 0.82(4)% [0.8%] ✓ working must be shown; allow ecf from i/ii but only if working is correct P_n = % uncertainty in $n = (P_{2-0}) + (P_{2-1})$ = 1.38(4)% (accept 1.4 %) ✓ for ecf from i/ii working in iii must be valid; for AE in iii allow ecf in final calculation [max and min values calculated, eg $n_{min} = \frac{14.28 - 0.08}{9.71 + 0.08}$, $n_{max} = \frac{14.28 + 0.08}{9.71 - 0.08}$; difference = ½ range (✓) convert to % = 1.38 (± 0.02)% (✓)]	**2**
		Total	**4**

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