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General Certificate of Education (A-level)
June 2013

Physics **PHA/B6X**

(Specification 2450/2455)

Unit 6X: 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 students' 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 students' 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.

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Section A Task 1				
1	(a)	results:	r_1 and r_2 to nearest mm (don't penalise if $r_1 > r_2$); both nT_1 and nT_2 (i.e. raw timings) to 0.1 s or both to 0.01 s ✓	1
		method:	T_1 (and/or T_2) from nT where n or $\Sigma n \geq 20$ ✓ (withhold mark for oscillations in a fixed time)	1
1	(b)	result:	$\dfrac{r_2 - r_1}{(T_2 - T_1)(T_2 + T_1)}$ in cm s^{-2}, in range 23.6 to 26.1 or 25 ✓✓ [22.4 to 27.3 or 23, 24 or 26 ✓] (accept answers in mm s^{-2} or in m s^{-2}; accept 4 sf and don't penalise if $r_1 > r_2$ causes result to be negative)	2
1	(c)	technique:	use of set-square in a vertical plane (shorter side) placed against metre ruler and (other shorter side) aligned with lower surface of mass hanger (can be shown in sketch) [plane mirror placed in contact with [accept behind] the ruler and position of eye shown in line with bottom of mass hanger [explanation that eye position is adjusted until (bottom of) mass is aligned with [hides] its reflection (can be shown in sketch)] $_1$✓	1
		explanation:	to avoid parallax error $_2$✓	1
1	(d)(i)	description:	the amplitude of M_3 decreases to a minimum [zero] as the amplitude of M_4 increases (to a maximum) and then the process reverses $_1$✓ (it must be clear that the changes in amplitude are continuous, simultaneous and gradual) the mass that loses amplitude [driving the process] is ahead of the other [being driven] $_2$✓ (if reversal of energy transfer is mentioned then it must be clear that the driving oscillator is always ahead; if there is no mention of the reverse process of energy transfer then condone idea that M_3 is always ahead of M_4) (always by) $\dfrac{\pi}{2}$ (radians) [90°, ¼ of a cycle] $_3$✓ (idea that the driven oscillator is $\dfrac{3\pi}{2}$ ahead is worth $_{23}$✓)	3
1	(d)(ii)	results:	raw timings of τ for energy transfer from M_3 to M_4 and back again, recorded to 0.1 s or 0.01 s; τ from $n\tau$ where n or $\sum n \geq 3$, correct to SV ± 30% ✓	1

2	(a)	results:	4 sets of x, y_1 and y_2; smallest x between 95 mm and 105 mm and x range ≥ 150 mm ✓ (no credit for false data, e.g. reversed ruler or $x = x + 500$)	**1**
		significant figures:	x, y_1 and y_2 all to nearest mm; y values correctly calculated (condone rounding up to nearest mm), but insist on consistent tabulation within each of **all four** columns ✓ (do not penalise here for false data)	**1**
2	(b)	graph scales:	points should cover at least half the grid horizontally (5 major grid squares) and half the grid vertically (7 major grid squares); if necessary, a false origin, correctly marked, should be used to meet these criteria ✓ withhold the mark if either axis has the origin incorrectly marked or if any difficult, reversed or non-linear scale is used; do not penalise here for false data)	**1**
		points, line and quality:	all 4 points plotted correctly (check at least one including any anomalous points); at least 3 points to 2 mm of straight best fit line of positive gradient ✓ (no credit for false data: only penalise once for poorly marked points [line] here and in Section A Task 2)	**1**
2	(c)	method and result	G from valid working or 0/2; no unit, in range 0.75 to 0.84 (accept 2, 3 or 4 sf) ✓✓ [0.71 to 0.88 or 0.8 ✓] [allow full credit for $x = x + 500$; for reversed ruler use range(s) as above but insist on negative sign, or lose 1 mark]	**2**
				16

Section A Task 2				
1	(a)	accuracy:	T_0 in range 2.0(0) s to 5.0(0) s value sensible (i.e. greater than any T) ✓ if T_0 is **not** from nT_0 where n or $\Sigma n \geq 20$ deduct one results mark in (b); if raw reading(s) for nT_0 are not to the same precision as the raw readings for nT deduct SF mark in (b)	**1**
1	(b)	tabulation:	d / cm nT /s T (/s) ✓ withhold mark for any missing label, separator or unit: for omission of nT data allow tabulation mark for d/cm T/s but treat as n = 1 and penalise as described next	**1**
		results:	5 sets of d and nT ✓✓ deduct 1 mark for each missing set, if largest d < 50 cm, if smallest d < 25 cm or > 35 cm, if d/cm is not in the left-hand column or if any T (including T_0) is **not** from nT where n or Σn ≥ 20 (max deduction 2 marks)	**2**
		significant figures:	all (raw) nT and nT_0 to nearest 0.1 s or to nearest 0.01 s; all d to nearest mm ✓	**1**

1	(c)	tabulation:	$\log\left(\frac{1}{T^2}-\frac{1}{T_0^2}\right)$ log(*d*) ✓ (no need for bracket/unit here)	**1**
		significant figures:	all log(*d*) values recorded to 3 dp or to 4 dp (most significant figure for all log(*d*/cm) should be 1); condone ‘2’ for log(d/mm) ✓ [tolerate ln if applied to <u>both</u> sets; accept all ln(*d*) values to 3 sf or all to 4 sf]	**1**
		axes:	marked $\log\left(\left(\frac{1}{T^2}-\frac{1}{T_0^2}\right)/s^{-2}\right)$ (vertical) and log(*d*/cm) (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 ✓ 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, reversed or non-linear scale; deduct 1 mark if one or both axes have the origin incorrectly marked	**2**
		points:	5 points plotted correctly (check at least three including any anomalous points) ✓✓✓ 1 mark is deducted for every point missing, for every tabulated point not plotted and for every point > 1 mm from correct position deduct 1 mark if any point is poorly marked; no credit for false data (including the omission of a negative sign with $\log\left(\frac{1}{T^2}-\frac{1}{T_0^2}\right)$ data)	**3**
		line:	(ruled) best fit straight line of negative gradient ✓ maximum acceptable deviation from best fit line is 2 mm, adjust criteria if graph is poorly scaled; no credit for false data or if line is poorly marked	**1**
		quality:	5 points to ± 2mm of a straight line of negative gradient (judge from graph, providing this is suitably-scaled) ✓	**1**
				16

<table>
<tr><th colspan="2">Section B</th><th></th><th></th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">(a)</td><td>valid attempt at gradient calculation and correct transfer of data or $_{12}$✓ = 0
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 $_{2}$✓
(if a poorly-scaled graph is drawn the hypotenuse of the gradient triangle should be extended to meet the 8 × 8 criteria)</td><td>2</td></tr>
<tr><td>G in the range –3.15 to –2.85 or 2 sf answers in the range –3.1 to –2.9 ✓✓
[–3.30 to –2.70 or –3.2 or –2.8 ✓]
(ignore any unit given in error; deduct 1 mark for the omission of the minus sign unless false data has led to a positive gradient)</td><td>2</td></tr>
<tr><td rowspan="4">1</td><td>(b)(i)</td><td>(n is given by the gradient of the graph, hence nearest integer to G) n = –3 ✓
(no credit for non-integer value for n) [allow ecf for valid <u>non-zero</u> integer deduction if $n \neq -3$]</td><td>1</td></tr>
<tr><td>(b)(ii)</td><td>units for k are $cm^3\,s^{-2}$ ✓(allow m or mm for cm; no ecf if n was not given as an integer) [allow ecf for valid deduction of unit if $n \neq -3$]</td><td>1</td></tr>
<tr><td rowspan="2">(b)(iii)</td><td><u>vertical</u> (condone ‘y’) intercept on graph = log (k) ✓
(don’t insist on ‘read’/’find’ or ‘extrapolate line’)
when log(d) = 0, $\log\left(\frac{1}{T^2}-\frac{1}{T_0^2}\right)=\log(k)$ ✓
<u>horizontal</u> (condone ‘x’) intercept on graph = $\frac{-\log(k)}{n}$ ✓
$\log\left(\frac{1}{T^2}-\frac{1}{T_0^2}\right) = n\log(d) + \log(k)$ compared with y = mx + c so <u>c = log(k)</u> ✓
find log(k) by evaluating $\log\left(\frac{1}{T^2}-\frac{1}{T_0^2}\right) - n\log(d)$ for a <u>point on the line</u> ✓</td><td>1 MAX</td></tr>
<tr><td>$k = 10^{(\text{vertical intercept})}$ [<u>antilog</u> (tolerate ‘inverse log’ but reject ‘$\log^{-1}$’) of vertical intercept] ✓
$k = 10^{-n(\text{horizontal intercept})}$ ✓
$k = 10^{(\log k)}$ ✓</td><td>1 MAX</td></tr>
</table>

<table>
<tr><td>2</td><td>(a)(i)</td><td>4 <u>correct</u> values of τ/s: all to 3 sf or all to 4 sf ✓
<table><tr><th>d/cm</th><th>n</th><th>nτ/s</th><th>nτ/s</th><th>τ/s</th></tr><tr><td>86.0</td><td>6</td><td>212</td><td>209</td><td>35.1</td></tr><tr><td>78.0</td><td>5</td><td>236</td><td>240</td><td>47.6</td></tr><tr><td>70.0</td><td>6</td><td>408</td><td></td><td>68.0</td></tr><tr><td>65.0</td><td>4</td><td>347</td><td></td><td>86.8</td></tr></table></td><td>1</td></tr>
<tr><td>2</td><td>(a)(ii)</td><td>3 sf is justified since the nT values [timings] are 3 sf; no credit if all τ/s ≠ 3 sf in 2(a)(i) [condone ‘same as (measured) data (in table)’ as long as it can be inferred that this includes nT] ✓</td><td>1</td></tr>
</table>

<table>
<tr><td>2</td><td>(b)</td><td>evidence of <u>at least two</u> correct calculations of $d^2\tau$ recorded to 2 or more sf (treat trailing zeros as ambiguous) or $_{12}$✓ = 0: other valid ratios are acceptable [accept use of $d^2\tau$ to calculate result for τ for another value of d]

d/m | τ/s | $d^2\tau$ /m^2 s | [$d^{-2}\tau^{-1}$ /m^{-2} s^{-1}
0.860 | 35.1 | 26.0 [2.60 × 10^5 cm^2 s] | 38.5 × 10^{-2}
0.780 | 47.6 | 29.0 etc | 34.5 × 10^{-2}
0.700 | 68.0 | 33.3 etc | 30.0 × 10^{-2}
0.650 | 86.8 | 36.7 etc | 27.2 × 10^{-2}]

(accept minor rounding errors but candidate's values, when rounded to 2 sf, must agree with 26, 29, 33 and 37; allow ecf if 2 sf τ given in (a); there can be no ecf if wrong τ given in (a)) $_1$✓
valid observation (e.g. large <u>percentage</u> uncertainty (about mean) / large (absolute) variation about <u>mean</u> / large range [difference between largest and smallest values]) supported by <u>suitable calculation(s)</u>, hence the claim is <u>not justified</u> $_2$✓

[evidence of <u>four</u> correct calculations of $d^2\tau$ $_1$✓ statement that $d^2\tau$ increases as d decreases [as τ increases] so claim is <u>not justified</u> $_2$✓]
[$\frac{d_1^2}{d_2^2}$ compared to $\frac{\tau_2}{\tau_1}$, $\frac{d_2^2}{d_3^2}$ compared to $\frac{\tau_3}{\tau_2}$, etc, using data from <u>at least three</u> rows in the table (or $_2$✓ = 0): consistent recording and appropriate sf $_1$✓ valid observation so claim is <u>not justified</u> $_2$✓]</td><td>2</td></tr>
<tr><td>2</td><td>(c)</td><td>any 3 of the following, at least 2 of which should be <u>quantitative</u>: ✓
(same) <u>masses</u> (either or both masses may be mentioned but 'M$_3$ and M$_4$' does not count as 2 responses; allow 'size of the masses' but reject 'weight of the masses')
(same) spring <u>stiffness</u> [spring <u>constant</u>]
(allow 'same (type of) spring' as the one qualitative response allowed)
(same) ruler (<u>Young Modulus</u>, <u>stiffness</u>, <u>material</u>, <u>mass</u>) / ruler same way up /same <u>cross-sectional</u> area
<u>position</u> of springs on ruler
spring <u>separation</u> [<u>distance</u> between masses]
reject 'same initial displacement', 'length of spring', 'thickness of ruler', 'height of supports'</td><td>1</td></tr>
<tr><td>2</td><td>(d)(i)</td><td>sample rate = (25000/10 =) 2500 Hz [tolerate s^{-1}, accept 1 every 4 × 10^{-4} s] ✓</td><td>1</td></tr>
<tr><td>2</td><td>(d)(ii)</td><td>sensible working using Fig 9; T from nT where n or $\sum n \geq 15$
(e.g. $T = \frac{10}{28.5} = 0.35(1)$) ✓
sensible working using Fig 10; τ from $n\tau$ where n or $\sum n \geq 30$
(e.g. $\tau = \frac{246}{52} = 4.73$) ✓

$\frac{\tau}{T}$, no unit, in range 12.8 to 13.8; 3 sf or 4 sf only unless sf already penalised elsewhere in Section B ✓
[1 MAX if T and τ interchanged but result in range 7.25×10^{-2} to 7.82×10^{-2}]</td><td>3</td></tr>
</table>

3	(a)	to find x read off the position of the end of the magnet using (markings/scale on metre) ruler; x/cm = 50 – read off or wtte $_1$✓ measure θ using suitable rotary scale e.g. protractor [angle measurer] correctly positioned, e.g. placed above or below compass with centre of scale at the centre of the compass [metre ruler] (if the wording is not clear this mark can be earned for suitable annotation to Figure 11) [allow trig method if suitable linear measurements and method are identified; use of 'ruler' can be implied for this approach] $_2$✓ [for bland 'use the (metre) ruler to measure x and the protractor to measure θ allow $_{12}$✓] (to reduce systematic error in results for B) <u>remove magnet</u> to check direction of compass (when only subject to ambient magnetic field) [confirm that half-metre ruler and metre ruler are perpendicular using set-square or protractor] $_3$✓ (ignore references to avoiding parallax error) measure θ for different x (a mock-up of a table of results can be taken to infer that a range of data will be produced); plot graph of (B_0) tan θ against x [B against x] $_4$✓ [condone log-log plot if significance of gradient mentioned]	**3 MAX**
	(b)	$_d$✓ and $_e$✓ can be awarded independently but $_e$✓ must explain $_d$✓ for full credit magnetometer has a scale with large <u>diameter</u> [<u>radius</u>, <u>circumference</u>] $_d$✓ (reject 'larger scale', 'magnetometer is larger than compass', 'graduations more spread out' or 'long needle') means a small change in θ [B] produces a large (translational) movement of tip of pointer; [(compared with the compass) the magnetometer is more <u>sensitive</u>] $_e$✓	**3 MAX**
		magnetometer fitted with a mirror to help avoid <u>parallax error</u> [to ensure scale is read from directly above] $_d$✓ observer moves position until needle hides [is aligned with] its reflection in the mirror $_e$✓	
		magnetometer (unlike a compass) has a scale that enables angle to be found <u>directly</u> or wtte [(tip of) pointer reaches (rotary) scale] $_d$✓ eliminates the risk of misalignment [need to draw a line in the direction the compass points (to reach the scale on the protractor) / need to perform trig calculation or wtte] $_e$✓ (reject bland 'reduces uncertainty')	
			23