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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.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' 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.

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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 $\Sigma n \geq 20$ ✓<br>(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 ✓✓<br>[22.4 to 27.3 or 23, 24 or 26 ✓]<br>(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)<br>[plane mirror placed in contact with [accept behind] the ruler and position of eye shown in line with bottom of mass hanger<br>[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 $_1$✓<br>(it must be clear that the changes in amplitude are continuous, simultaneous and gradual)<br>the mass that loses amplitude [driving the process] is ahead of the other [being driven] $_2$✓<br>(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 $M_4$)<br>(always by) $\frac{\pi}{2}$ (radians) [90°, ¼ of a cycle] $_3$✓<br>(idea that the driven oscillator is $\frac{3\pi}{2}$ ahead is worth $_{23}$✓) | 3 |
| 1 (d)(ii) | results: | raw timings of $\tau$ for energy transfer from $M_3$ to $M_4$ and back again, recorded to 0.1 s or 0.01 s; $\tau$ 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 $\geq$ 150 mm ✓<br>(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 <u>rounding up</u> to nearest mm), but insist on consistent tabulation within each of **all four** columns ✓<br>(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) <u>and</u> half the grid vertically (7 major grid squares); if necessary, a false origin, correctly marked, should be used to meet these criteria ✓<br>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 <u>positive</u> gradient ✓<br>(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; <u>no unit</u>, in range 0.75 to 0.84 (accept 2, 3 or 4 sf) ✓✓<br>[0.71 to 0.88 or 0.8 ✓]<br>[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 $T$) ✓<br>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) ✓<br>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 $nT$ ✓✓<br>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 $\Sigma n$ ≥ 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) ✓<br>[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) ✓✓<br>deduct ½ for each missing label or separator, rounding down; no mark if axes reversed<br>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 ✓<br>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) ✓✓✓<br>1 mark is deducted for every point missing, for every tabulated point not plotted and for every point > 1 mm from correct position<br>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 ✓<br>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 <u>+</u> 2 mm 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<br>correct transfer of $y$- and $x$-step data between graph and calculation $_1$✓<br>(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)<br>$y$-step and $x$-step both at least 8 semi-major grid squares $_2$✓<br>(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 ✓✓<br>[–3.30 to –2.70 or –3.2 or –2.8 ✓]<br>(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 ✓<br>(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 ($k$) ✓<br>(don’t insist on ‘read’/’find’ or ‘extrapolate line’)<br>when log($d$) = 0, $\log\left(\frac{1}{T^2}-\frac{1}{T_0^2}\right)$=log($k$) ✓<br><u>horizontal</u> (condone ‘$x$’) intercept on graph = $\frac{-\log(k)}{n}$ ✓<br>$\log\left(\frac{1}{T^2}-\frac{1}{T_0^2}\right) = n\log(d) + \log(k)$ compared with $y = mx + c$ so <u>$c = \log(k)$</u> ✓<br>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] ✓<br>$k = 10^{-n(\text{horizontal intercept})}$ ✓<br>$k = 10^{(\log k)}$ ✓</td><td>1 MAX</td></tr>
</table>

<table>
<tr><td>2</td><td>(a)(i)</td><td>4 <u>correct</u> values of $\tau$/s: all to 3 sf or all to 4 sf ✓
<table>
<tr><th>$d$/cm</th><th>$n$</th><th>$n\tau$/s</th><th>$n\tau$/s</th><th>$\tau$/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 $\tau$/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 at least two 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 $\tau$ for another value of $d$]<br>
<table>
<tr><th>$d$/m</th><th>$\tau$/s</th><th>$d^2\tau$ /m$^2$ s</th><th>[$d^{-2}\tau^{-1}$ /m$^{-2}$ s$^{-1}$</th></tr>
<tr><td>0.860</td><td>35.1</td><td>26.0 [2.60 × 10$^5$ cm$^2$ s]</td><td>38.5 × 10$^{-2}$</td></tr>
<tr><td>0.780</td><td>47.6</td><td>29.0 etc</td><td>34.5 × 10$^{-2}$</td></tr>
<tr><td>0.700</td><td>68.0</td><td>33.3 etc</td><td>30.0 × 10$^{-2}$</td></tr>
<tr><td>0.650</td><td>86.8</td><td>36.7 etc</td><td>27.2 × 10$^{-2}$]</td></tr>
</table>
(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 $\tau$ given in (a); there can be no ecf if wrong $\tau$ given in (a)) ${}_1$✓<br>
valid observation (e.g. large percentage uncertainty (about mean) / large (absolute) variation about mean / large range [difference between largest and smallest values]) supported by suitable calculation(s), hence the claim is not justified ${}_2$✓<br><br>
[evidence of four correct calculations of $d^2\tau$ ${}_1$✓ statement that $d^2\tau$ increases as $d$ decreases [as $\tau$ increases] so claim is not justified ${}_2$✓]<br>
[ $\frac{d_1^2}{d_2^2}$ 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 at least three rows in the table (or ${}_2$✓ = 0): consistent recording and appropriate sf ${}_1$✓ valid observation so claim is not justified ${}_2$✓]</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 quantitative: ✓<br>
(same) masses (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')<br>
(same) spring stiffness [spring constant]<br>
(allow 'same (type of) spring' as the one qualitative response allowed)<br>
(same) ruler (Young Modulus, stiffness, material, mass) / ruler same way up /same cross-sectional area<br>
position of springs on ruler<br>
spring separation [distance between masses]<br>
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 $\sum n \geq 15$<br>
(e.g. $T = \frac{10}{28.5} = 0.35(1)$ ) ✓<br>
sensible working using Fig 10; $\tau$ from $n\tau$ where $n$ or $\sum n \geq 30$<br>
(e.g. $\tau = \frac{246}{52} = 4.73$ ) ✓<br><br>
$\frac{\tau}{T}$, no unit, in range 12.8 to 13.8; 3 sf or 4 sf only unless sf already penalised elsewhere in Section B ✓<br>
[1 MAX if $T$ and $\tau$ interchanged but result in range 7.25×10$^{-2}$ to 7.82×10$^{-2}$]</td>
<td>3</td>
</tr>
</table>

<table>
<tr><td rowspan="4">3</td><td>(a)</td><td>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 $_1$✓<br>measure $\theta$ 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)<br>[allow trig method if suitable linear measurements and method are identified; use of 'ruler' can be implied for this approach] $_2$✓<br>[for bland 'use the (metre) ruler to measure x and the protractor to measure $\theta$ allow $_{12}$✓]<br>(to reduce systematic error in results for B) <u>remove magnet</u> to check direction of compass (when only subject to ambient magnetic field)<br>[confirm that half-metre ruler and metre ruler are perpendicular using set-square or protractor] $_3$✓ (ignore references to avoiding parallax error)<br>measure $\theta$ 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 $\theta$ against x [B against x] $_4$✓ [condone log-log plot if significance of gradient mentioned]</td><td>3 MAX</td></tr>
<tr><td rowspan="3">(b)</td><td>$_d$✓ and $_e$✓ can be awarded independently but $_e$✓ must explain $_d$✓ for full credit<br>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')<br>means a small change in $\theta$ [B] produces a large (translational) movement of tip of pointer; [(compared with the compass) the magnetometer is more <u>sensitive</u>] $_e$✓</td><td rowspan="3">3 MAX</td></tr>
<tr><td>magnetometer fitted with a mirror to help avoid <u>parallax error</u> [to ensure scale is read from directly above] $_d$✓<br>observer moves position until needle hides [is aligned with] its reflection in the mirror $_e$✓</td></tr>
<tr><td>magnetometer (unlike a compass) has a scale that enables angle to be found <u>directly</u> or wtte [(tip of) pointer reaches (rotary) scale] $_d$✓<br>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')</td></tr>
<tr><td></td><td></td><td></td><td>23</td></tr>
</table>