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General Certificate of Education (A-level)
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**Physics** **PHA3/B3/X**

## Unit 3: Investigative and practical skills in AS Physics

# Final

# *Mark Scheme*

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**GCE Physics, PHA3/B3/X, Investigative and Practical Skills in AS Physics**

**Section A, Part 1**

| **Question 1** | | | | |
|---|---|---|---|---|
| a i | method | *d* from repeat readings, (all) to 0.01 mm ✓ | | **1** |
| a ii | accuracy | SWG number = 22 ✓ | | **1** |
| b i/ii | accuracy | $V_1$ and $V_2$ sensible, both to 0.01 or both to 0.001 V, $V_1$ in range $4V_2$ to $6V_2$ ✓ | | **1** |
| b iii | accuracy | 2 raw readings recorded to the nearest mm; *x* from the difference in raw readings in range 300 mm to 380 mm ✓ | | **1** |
| c i | method | percentage uncertainty in $V_1 = \frac{0.01}{V_1} \times 100$ (eg where $V_1$ in $V$)<br>expect at least 2 sf answer ✓ (allow ecf from bii) | | **1** |
| c ii | method | percentage uncertainty in $V_2 = \frac{0.01}{V_2} \times 100$ (eg where $V_2$ in $V$)<br>expect at least 2 sf answer ✓ (allow ecf from bii)<br>if both ci & cii results are given to 1 sf then only deduct one mark | | **1** |
| d | method | percentage uncertainty in *R* = (sum of percentage uncertainties in $V_1$ and $V_2$) + 5%; max 4 sf result ✓ (allow ecf from c) | | **1** |
| e | method | evaluates resistance per metre of wire using $\frac{R_{PQ}}{x}$ (expect evidence of calculation) ✓ | | **1** |
| | deduction | type of wire = **constantan**; result for $\frac{R_{PQ}}{x}$ must be in range 1.14 to 1.49 ($\Omega\,m^{-1}$) and SWG must = 22 ✓<br>(no ecf for wrong SWG and/or wrong resistance per metre) | | **1** |
| | | | **Total** | **9** |

| **Question 2** | | | |
|---|---|---|---|
| a | observations | $\theta_0$ recorded with a unit; 6 sets of $\theta$ recorded in column 2 of **Table 3**, consistently to the nearest ° (tolerate nearest 2° or nearest 5°), sensible values of $\theta$, all greater than $\theta_0$ and in ascending order ✓<br>6 sets of ($\theta - \theta_0$), correctly calculated (check at least one) ✓ | **2** |
| b | scale | vertical scale to cover at least half the grid vertically; use of false origin should be marked properly ✓<br>(allow reversed potentiometer and do not penalise here for false data) | **1** |
| | points | 6 plotted correctly to nearest mm (allow reversed potentiometer but give no credit for false or incorrectly calculated data; check at least two including any anomalous points; withhold mark for any thick or missing point(s)) ✓ | **1** |
| | line/quality | from a **smooth** curve of positive continuously decreasing gradient from $R$ = 1 kΩ to $R$ = 39 kΩ (tolerate 1 straight line section between adjacent points; maximum acceptable deviation is 2 mm, adjust criterion if poorly-scaled; allow **smooth** curve of negative continuously decreasing gradient for reversed potentiometer but give no credit for false data or thick/hairy line); no point to be further than 2 mm from best-fit line ✓ | **1** |
| c | method and accuracy | $\theta_U$ recorded to the nearest ° (do not penalise missing unit if already penalised for $\theta_0$); evidence shown (eg on the graph) that position of $\theta_U - \theta_0$, correct to the nearest mm, has been used to determine $R_U$ ✓<br>value of RU with appropriate unit, read off correct to the nearest mm, result in the range 8.1 kΩ to 10.1 kΩ (tolerate 9 kΩ, reject 10 kΩ) ✓ | **2** |
| | | **Total** | **7** |

**Section A, Part 2**

| **Question 1** | | | |
|---|---|---|---|
| a | accuracy | negative $V_{20}$ and positive $V_{260}$, with unit, values sensible (do not penalise for reversed polarity if consistent with (b))<br>$\frac{V_{260}}{V_{20}}$, negative, 3 sf or 4 sf and same sf as for $V_{20}$ and $V_{260}$,<br>no unit, result in range –1.45(0) to –1.38(0) ✓ | **1** |
| b | tabulation | $x$ /mm $V$ /V ✓✓<br>deduct ½ for each missing or wrongly-connected label<br>deduct ½ for each missing separator, rounding down<br>penalise if $x$/mm is not in the left-hand column of the table | **2** |

| | | | |
|---|---|---|---|
| | results | at least 11 **additional** sets of *x* and *V* (ie $\Delta x$ = 20 mm) ✓✓<br>[at least 7 **additional** sets of *x* and *V* (ie $\Delta x$ = 30 mm) ✓]<br>if both polarities not given then 1 max and allow ecf in c for line and quality; if conductive paper has been reversed deduct both marks here but allow ecf for points | **2** |
| | significant figures | all *x* to nearest mm and all *V* (including $V_{20}$ and $V_{260}$) to nearest mV or to the nearest 0.01 V ✓<br>(tolerate a mixed approach to tabulation of *V* if meter reading is auto-ranging, ie all given to 3 sf) | **1** |
| c | axes | marked *V*/V (vertical) and *x*/mm (horizontal) ✓✓<br>deduct ½ for each missing label or separator, rounding down; [bald *V* (vertical) and *x* (horizontal) ✓]<br>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 ✓<br>**and** half the grid vertically ✓<br>[a 1 quadrant plot can earn1 max]<br>(either or both marks may be lost for use of a difficult or non-linear scale) | **2** |
| | points | points from a and b plotted correctly (check at least two for *V* negative and two for *V* positive, including any anomalous points) ✓✓✓<br>1 mark is deducted for<br>every item of data (including $V_{20}$ and $V_{260}$) missing from the graph<br>every point > 1 mm from correct position; a one quadrant plot loses all 3 marks<br>any point poorly marked; tolerate 1 quadrant graph here | **3** |
| | line | two straight-line (ruled) regions of positive gradient; accept these joined (reject crossed lines) by smooth curve of positive increasing gradient; maximum acceptable deviation is 2 mm, adjust criterion if graph poorly-scaled ✓<br>[allow ecf for reversed polarity] (a 1 quadrant plot loses this mark) | **1** |
| | quality | at least 8 points plotted; mark is forfeited for **any point** > 2mm from a trend illustrating 2 linear regions of positive gradient [allow ecf for reversed polarity] (judge from graph, providing it is suitably-scaled); 1 quadrant plot loses this mark ✓ | **1** |
| | | **Total** | **15** |

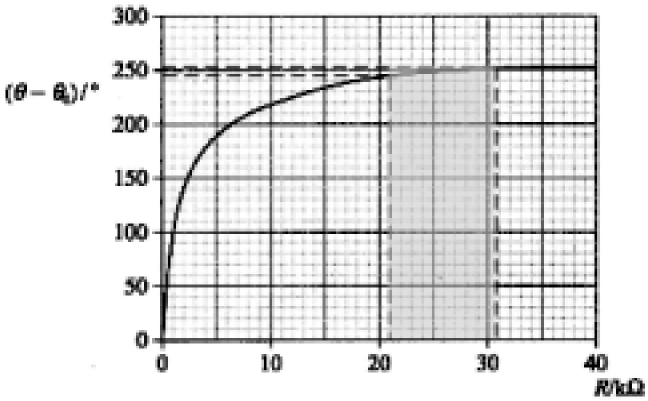
**Section B**

| **Question 1** | | | |
|---|---|---|---|
| a | i/ii | evidence from the graph that the line has been extrapolated at each end (tolerate extension of line to the edge of the grid as long as this does not extend into the margins; tolerate if single straight line or curve is drawn)<br>both *V* read offs correct to 1 mm if directly read off the graph; do not insist on a unit (if scale does not allow direct read off, expect evidence that values of $V_0$ and/or $V_{280}$ have been calculated using valid gradients of each linear region, values approximately correct by eye) ✓ | **1** |
| a | iii | $x_0$ read off correct from graph to 1 mm (tolerate if single straight line or curve is drawn) ✓ | **1** |
| b | i | valid attempt at gradient calculation and correct transfer of data **or** $_{\mathbf{12}}$**✓= 0** (if a curve is drawn in error a tangent should be drawn to form the hypotenuse of the triangle)<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>[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** |
| b | ii | positive result [allow ecf for reversed polarity], no unit, in the range 0.576 to 0.606 or 2 sf answer in range 0.58 to 0.60 ✓✓<br>[0.561 to 0.620, 0.57 or 0.61 ✓] (no effect on result if polarity is reversed) | **2** |
| | | **Total** | |

| **Question 2** | | | |
|---|---|---|---|
| a | i | *G* will be lower ✓ | **1** |
| a | ii | $\frac{V_{260}}{V_{20}}$ will be the same (reject 'similar' or 'roughly the same') ✓ | **1** |
| b | | because all values of *V* are **proportionally** lower [lower by same percentage or factor] ✓ (reject '$V_0$ and $V_{280}$ decrease at the same rate')<br>(award mark if given as explanation to either **correct** prediction; reject $V_{260}$ and $V_{20}$ are in the same proportion) | **1** |
| | | **Total** | **3** |

| **Question 3** | | |
|---|---|---|
| a | read off *x*) where the **gradient** of the graph changes [increases/steepens] ✓<br>(reject 'where the graph starts to curve' or 'where trend changes')<br><br>(condone 'find *x* where straight lines meet' but do not credit again in (b)) | **1** |
| b | **either**<br><br>student A's argument is better, consistent with candidate's graph (ie curve between linear regions; reject 1 quadrant plot) ✓<br><br>(graph shows) gradient changes over a **range of *x* values** ✓<br><br>can locate point where width changes by determining the **centre** of the curving region ✓<br><br>more points at this part will help define the shape (of the curve) [improve the detail (of the graph) where the gradient changes] ✓ (reject 'identify/eliminate anomalies')<br><br>**or**<br><br>student B's argument is better, consistent with candidate's graph (two linear regions intersecting at a point; reject 1 quadrant plot) ✓<br><br>(idea that) the linear regions intersect at a **specific value of *x*** [where straight line regions meet or intersect] ✓<br><br>can locate point where width changes (by extrapolating lines) and finding where lines **meet** [cross] ✓<br><br>more points will reduce the impact of **random** error of the **gradients** [make **gradient/line** more **reliable** [identify/eliminate anomalous results] ✓ (reject 'reduce random error in points' or 'make points/data more reliable') | **max 2** |
| | **Total** | **3** |

| **Question 4** | | |
|---|---|---|
| i | idea that the wire may not have uniform cross-section [diameter] ✓<br>(accept 'uneven wire'; reject 'kink' or 'bend' in the wire, or other ideas such as parallax or any other form of human error) | **1** |
| ii | repeat the measurement **at a different point** (on the wire) [with the micrometer in a different direction] ✓<br><br>calculate an average result [check/reject any anomalous results] ✓ | **2** |
| iii | procedure: **close jaws** and check reading (= zero) ['check for **zero error**'] ✓<br><br>(reject idea of measuring 'known' dimension and checking reading or comparing with readings made using a different instrument) | **1** |
| | **Total** | **4** |

| Question 5 | | |
|---|---|---|
| i | ± 3 ✓ | **1** |
| ii | idea that when $R_U$ is approximately 25 kΩ the gradient of the graph is small [tolerate 'graph is flat/horizontal'] ✓<br><br>the (small) uncertainty in $\theta - \theta_0$ produces a large uncertainty in $R_U$ [plausible values suggested, eg from ≈ 20 kΩ to >40 kΩ] ✓<br><br>(reject idea that vertical scale is not precise enough)<br><br>a sketch that conveys how the uncertainty (roughly correct) in $\theta - \theta_0$ produces a correspondingly larger uncertainty in $R_U$ is worth both marks, eg<br><br><br><br><br>both marks can be earned for a valid calculation of the uncertainty, or percentage uncertainty, in $R_U$ based on the idea illustrated in the sketch | **2** |
| | **Total** | **3** |

| **Question 6** | | |
|---|---|---|
| a | all 5 values of *k* correctly calculated to ≥ 3 sf ± 0.0001 (accept 2 sf for rows 1 and 2) ✓✓ [1 error = 1 max, all 2 sf = 1 max]<br><br>(accept reverse working, eg calculation of *k* for *R* = 2.9 Ω, *L* = 6.6 cm, then calculation of remaining *R* values using $kL^2$; results should all be consistent with values in column 2 of **Table 4**)<br><br>*L*/cm ; *R*/Ω ; $R/L^2$ ; $R/L^2$ (2 sf)<br>6.6 ; 2.9 ; 0.0666 [0.067] ; 0.067<br>10.6 ; 7.6 ; 0.0676 [0.068] ; 0.068<br>13.8 ; 13.0 ; 0.0683 ; 0.068<br>17.8 ; 21.6 ; 0.0682 ; 0.068<br>21.4 ; 30.4 ; 0.0664 ; 0.068<br><br>statement that (all) *k* values **are consistent** so **theory is correct** ✓<br><br>[for error(s) in *k* allow 'reject theory' providing largest *k* ÷ smallest *k* ≥ 1.10; if all $R/L^2$ shown as 0.07 then 'accept theory' is worth 1 max] | **3** |
| b | correct use of **average** value of *k* from at least 3 rows of **Table 4** (expect to see 0.0674, 0.067 or 0.07 but condone minor variations) and *R* = 3.8 Ω in calculation of *L* ✓<br><br>$L = \left(\sqrt{\frac{3.8}{6.74\times10^{-2}}}\right)$ = 7.5(1) **cm** ✓<br><br>(accept 2 or 3 sf answers with unit in range 7.4(0) to 7.6(0); no ecf for false average *k*) | **2** |
| | **Total** | **5** |

| | | |
|---|---|---|
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