A-LEVEL
PHYSICS

PHA3/B3/X – Investigative and practical skills in AS Physics
Mark scheme

2450
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Version 1.0 Final

Mark schemes are prepared by the Lead Assessment Writer 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 associates 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 associate understands and applies it in the same correct way. As preparation for standardisation each associate 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, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

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:	*h* and *x* for *m* = 200 to nearest mm (unit must be supplied at least once); 5 sets of *m* and *x*; all *x* to nearest mm, values increasing as *m* increases (*x* = 0 for *m* = 200 required; *x* for *m* = 600 should be consistent with tabulated value) ✓	**1**
1	(b)	graph:	suitable vertical scale: points should cover at least half the grid vertically (withhold mark for use of a difficult or non-linear scale) ✓ 5 points plotted correctly (check at least two against values in Table 1 including any anomalous points); (ruled) straight best fit line of positive gradient [allow curve if plotted points justify this]; maximum acceptable deviation from best fit line is 2 mm, adjust criteria if graph is poorly scaled; withhold mark if line is poorly marked ✓	**2**
1	(c)	explanation:	measure vertical height to string from bench at two or more (well-separated) points (a sketch showing two suitable positions for a ruler made vertical with a set-square against the bench can earn this mark) $_1$✓ check heights are the same $_2$✓ [compared string with horizontal edge of set square held against vertical ruler or against (vertical) string joined to mass hanger $_{12}$✓]	**2**
1	(d)(i)/ (d)(ii)	result and deduction:	x_U recorded to nearest mm; m_H recorded to nearest g; correct unit required here or in (d)(iii) for m_H (and no conflict); evidence of working on graph to show x_U read off correct to nearest mm (expect a horizontal and vertical line extending from each axis intersecting at the line) ✓	**1**
1	(d)(iii)	deduction:	mass of U in range 330 g to 350 g [0.34 kg] ✓✓ [320 g to 360 g, 0.33 kg or 0.35 kg ✓] (don't penalise missing unit here if given for m_H; no ecf for wrong read off, don't deduct for > 4sf answer)	**2**
1	(e)(i)	explanation:	(all) the (*x* or OP) values [range] (condone '*x* extension') would be greater $_1$✓ by the same fraction [percentage/by 50%] [3 each extend the same as each of 2 did / stiffness reduced by 1/3 / stiffness becomes 2/3] (allow $\frac{1}{k_{total}} = \frac{1}{k} + \frac{1}{k} + \frac{1}{k}\left[= \frac{3}{k}\right]$)] $_2$✓ the gradient of the graph would be greater [graph would be steeper] $_3$✓ [gradient steeper by factor of 1.5 earns $_2$✓$_3$✓]	**3**
1	(e)(ii)	explanation:	value of U would be unchanged/same (reject 'similar' or ideas about reduced uncertainty) ✓	**1**
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Section A Task 2				
1	(a)	accuracy:	ε and V_X recorded to 0.01 V or to 0.001 V, precision consistent with that for raw data in part (b) or lose SF mark in (b); the unit must be seen for at least one of ε or V_X $\frac{\varepsilon}{V_X}$ no unit, in range 1.06 to 1.10, minimum 3 sf but allow > 4sf (but then withhold sf mark in (c)) ✓ **note that this is the only part of Section A where excessive sf are penalised**	**1**
1	(a)(iv)	explanation:	mark awarded for any correct statement, eg voltmeter readings (for ε and V_X) would be lower (or 0/2) (condone 'ε is the same' but don't allow contradiction, eg 'reading for ε is the same') ✓ some pd dropped (condone 'lost') across contact resistance (at P and/or N) (reject $V = IR$ argument, 'lower current', 'greater circuit/internal resistance' or idea that contact resistance adds to internal resistance) ✓	**2**
1	(b)	tabulation:	R / Ω V / V [or mV] ✓ withhold mark for any missing label or separator: only give credit if units are supplied in the table headings; allow 'voltage' or 'pd' for V but reject 'volts' or 'voltmeter reading'	**1**
		results:	7 sets of R and V, values of R correctly calculated to the nearest Ω: 154 Ω, 115 Ω, 107 Ω, 86 Ω, 68 Ω, 47 Ω, 39 Ω) ✓✓ deduct 1 mark for each missing set and for each wrongly calculated value of R (max deduction 2 marks) deduct 1 mark if any calculation of R is incomplete, eg 39 + 47 + 68 when 154 is required deduct 1 mark if R is not in the left-hand column of a table with data arranged in columns or if the data is not recorded in a single coherent table	**2**
		significant figures:	all V (including ε and V_X) to nearest 0.01 V or all to nearest 0.001 V ✓	**1**

Section A Task 2 continued				
1	(c)	tabulation:	$\frac{1}{R}$ $(/\,\Omega^{-1})$ $\frac{\varepsilon}{V}$ (no unit) ✓ (accept either order)	**1**
		significant figures:	all $\frac{\varepsilon}{V}$ (including $\frac{\varepsilon}{V_X}$) to 3 sf or all to 4 sf (ignore sf in $\frac{1}{R}$; don't penalise if the derived data is recorded with the raw data in (b)) ✓	**1**

		axes:	marked $\frac{\varepsilon}{V}$ (no unit), $\frac{1}{R}/\Omega^{-1}$ [$/\frac{1}{\Omega}$] ✓✓ deduct ½ for each missing label or separator, rounding down; no mark if axes are reversed; don't penalise here for missing separator if already penalised in (b); deduct ½ for unit wrongly supplied with $\frac{\varepsilon}{V}$ unless already penalised in (a); accept appropriate use of multiplier consistent with numerical values on axes, eg $\frac{1}{R}$ (×) $10^3/\Omega^{-1}$ or / 10^{-3} (×) Ω^{-1}, or /kΩ^{-1} 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 should be used to meet these criteria and this must be clearly marked; either or both marks may be lost for use of a difficult or non-linear scale)	**2**
		points:	all tabulated points plotted correctly (check at least three, including any anomalous points); 6 or 7 ✓✓✓ [5 ✓✓, 4 ✓] 1 mark is deducted for each item of false data a mark is deducted for each plotted point for which the data has not been tabulated 1 mark is deducted if any point is poorly marked (don't deduct here for poorly marked points if deduction has already been made in Task 1) and for every point > 1 mm from correct position	**3**
		line:	(ruled) best fit straight line of positive gradient ✓ maximum acceptable deviation from best fit line is 2 mm, adjust criteria if graph is poorly scaled; withhold mark if line is poorly marked (don't deduct here for poorly marked line if deduction has already been made in Task 1)	**1**
		quality:	at least 6 points to ± 2 mm of a suitable line of positive constant gradient (judge from graph and adjust criteria if graph is poorly scaled) ✓	**1**
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Section B			
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) [for POT error $_{12}$✓=1 MAX and allow ecf in (c)(iii)]	**2**
1	(a)(ii)	*I*, no unit, in range 0.99 to 1.01; evidence of working is required, either algebra or direct read off (reject 1 sf or 2 sf answers)✓	**1**
1	(b)	graph (of $\frac{\varepsilon}{V}$ against $\frac{1}{R}$) is <u>linear</u>/<u>straight line</u> [of form <u>*y = mx + c*</u>] $_1$✓ $\frac{\varepsilon}{V}$ = *y* and $\frac{1}{R}$ = *x* [graph plotted was $\frac{\varepsilon}{V}$ against $\frac{1}{R}$] $_2$✓ *r* is equal to gradient [*m*] $_3$✓ [unambiguous statement that $\frac{\varepsilon}{V}=\left(r\times\frac{1}{R}\right)+1$ is of form *y* = *(m × x) + c, or* straightforward comparison, eg aligned equations, $\frac{\varepsilon}{V}=\left(r\times\frac{1}{R}\right)+1$ / $y=(m\times x)+c$ earns $_{123}$✓✓✓; rearrangement to $\frac{\varepsilon}{V}=\left(r\times\frac{1}{R}\right)+1$ so *r* = gradient earns $_2$✓$_3$✓] [when $\frac{\varepsilon}{V}$ = 2, $\frac{r}{R}$ = 1 [*r* = *R*] $_1$✓; <u>calculate</u> $\frac{1}{R}$ corresponding to $\frac{\varepsilon}{V}$ = 2 $_2$✓; *r* = reciprocal of the value of $\frac{1}{R}$ (that corresponds to $\frac{\varepsilon}{V}$ = 2) $_3$✓] (reject idea for $_3$✓ that *r* can be found by using $\left(\frac{\varepsilon}{V}-1\right)\times R$ using tabulated values unless these <u>lie on the line</u> or an <u>average</u> of several of ratios is to be calculated)	**3**

1	(c)(i)	the voltmeter has infinite [very high] resistance [no current flows in voltmeter/circuit] ✓	**1**
1	(c)(ii)	sensible reference to the internal resistance, eg (current flows in power supply leading to) pd across [energy transformed in] the internal resistance [($V_X < \varepsilon$ because $\varepsilon = V + Ir$ and) Ir is no longer zero] (condone 'some voltage [emf] is lost across internal resistance'; reject idea that internal resistance increases) ✓	**1**
1	(c)(iii)	$\dfrac{GV_X}{\varepsilon - V_X}$ with unit, in range 123 Ω to 136 Ω ✓✓ [116 Ω to 142 Ω ✓] (ecf for wrong multiplier with $\dfrac{1}{R}$ in Task 2) **note that this is the only part of Section B where excessive sf are penalised**	**2**

2	(a)	6 points plotted correctly to 1 mm (check one, including any anomalous points); smooth curve to 2 mm of all 6 points, of decreasing negative gradient drawn up to n = 20; this mark is deducted if any point is poorly marked or if the line is poorly marked (don't deduct here for poorly marked points or line if deduction has already been made in Task 1 or in Task 2) ✓	**1**
		value of V_{20} read off correctly, in range 0.3(0) to 0.4(0) (V); allow 1 sf ✓	**1**
2	(b)	$P = P_{max}$ when n = 5.75 to 5.85 (accept evidence of valid read off in working; withhold mark if unit supplied) $_1$✓ $\dfrac{1}{R} = \left[\dfrac{1}{r}\right] = \dfrac{n}{22} (\therefore r = \dfrac{22}{5.80})$ $\left[\text{working to this effect, eg } \dfrac{1}{r} = \dfrac{1}{22} + \dfrac{1}{22} + \dfrac{1}{22} + \dfrac{1}{22} + \dfrac{1}{22} + \dfrac{(n-5)}{22} = \dfrac{23}{88}\right]$ [read off P_{max} from Figure 14 (expect to see161 mW); evidence from line drawn from n axis to curve then line drawn to V axis, that V read off from Figure 13 for $P = P_{max}$ (should get 0.78 V); $r = \dfrac{V^2}{P}$ when $P = P_{max}$ $_2$✓] r in range 3.70 Ω to 3.89 Ω or 3.8 Ω □(don't penalise for excessive sf)$_3$✓	**3**

3	(a)(i)	connect a resistor of known resistance (between X and Y) $_1$✓ or $_2$✓= $_3$✓= 0 mark [record] on the scale (the position of the needle for) this (resistance) value; (don't give credit for simply marking 0 Ω or ∞ Ω) $_2$✓ or $_3$✓= 0 repeat for different resistors (that cover the whole range of the needle movement) $_3$✓ [read/record scale reading [current] (for resistor of known resistance) $_2$✓; plot a (calibration) graph (of resistance against scale reading [current]) $_3$✓]	**3**
3	(a)(ii)	no change in the (resistance) reading ✓	**1**
		(resistance) reading is increased [needle moves further to left] (ignore reference to current unless this conflicts with statement about how resistance reading changes) ✓	**1**
3	(b)(i)	difficult to interpolate [estimate the resistance when the needle falls between (any) marked graduations] (ignore difficult to read larger resistances) $_1$✓ states that the scale is non-linear [values / numbers / markings / graduations / divisions are not evenly-spaced / do not go up by same factor / increase at changing rate; intervals / increments / steps are not the same / even / regular / constant difference/distance between values / markings / graduations / intervals / divisions changes [can use example from Figure 17 to illustrate this]; same distance on scale does not represent the same change in value / reading (as resistance changes)] (reject scale does not go up at regular intervals / scale does not up by same factor / is not even / doesn't go up at a normal rate / is different in different places / goes backwards) $_2$✓	**2**
3	(b)(ii)	idea that should view scale so that needle hides [lines up with] its reflection [reflection of needle is hidden when viewed from directly above the needle] ✓ eliminates [avoids/reduces] parallax (error) [ensures that the scale is viewed normally / view is perpendicular to scale] (reject 'cannot see reflection') ✓	**2**
3	(b)(iii)	uncertainty increases as the resistance increases [uncertainty decreases as resistance decreases] (ignore reference to error or to accuracy) ✓	1
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