AQA

A-Level
Physics

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

2450/2455
June 2016

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.

Further copies of this mark scheme are available from aqa.org.uk

Section A Task 1				
1	(a)	readings:	x_1, x_2, x_3 and x_4 each recorded to the nearest mm; the unit must appear at least once ✓ condone all raw readings to nearest 0.5 mm; reject all trailing zeros	**1**
1	(b)	result:	$\frac{2m(x_1 - x_3)}{2x_4 + x_2}$ to 3 sf or to 4 sf with suitable unit, value in range SV ± 2% ✓✓ [SV ± 5% ✓] **note that this is the only part of Section A where excessive sf are penalised**	**2**
1	(c)	explanation:	measure vertical height [*h*] to half-metre ruler from bench at two or more (well-separated) points [give credit for sketch showing set-square arranged against metre ruler and the bench at two suitable positions / allow use of set-square without vertical ruler alongside if positioning is sensible] $_1$✓ check heights are the same $_2$✓ [use of set-square between half metre ruler and vertical metre ruler [perpendicular to desk] and half-metre ruler $_{12}$✓= 1 MAX] (reject idea that clamp stand is vertical or that edge of vertical ruler or set-square can be compared with the markings on the pivoted ruler)	**2**
1	(d)	explanation:	(x_1 and x_3 are both [1 cm] too large so) no effect on ($x_1 - x_3$) [numerator] $_1$✓ x_4 [denominator] is [1 cm] increased $_2$✓ result (for $\frac{2m(x_1 - x_3)}{2x_4 + x_2}$) decreased $_3$✓ (condone 'mass underestimated' but don't allow 'becomes negative') [prediction of change in result based on correct calculation of new value: must see evidence of values correctly substituted to earn $_1$✓ and $_2$✓ leading to full credit]	**3**

2	(a)(i) and (a)(iii)	evidence that procedure followed by annotation to Figure 4:	sensible outline of the block marked, top edge aligned with LR to nearest mm; ruled emergent ray marked on Figure 4; emergent ray ≈ parallel to PQ (by eye: *s* at exit must be no greater than 1 mm different to *s* at Q); ruled internal ray drawn joining points of entry and exit of ray to the block ✓ (don't insist on arrows showing direction of rays here or in or in (b)(i))	**1**
2	(a)(ii)	result for *s*:	sensible raw reading(s) of *s* recorded to nearest mm or to nearest 0.5 mm (whichever is consistent with recording of *x* values in 1(a); don't penalise here as well as in 1(a) for inconsistent precision) ✓ evidence marked on Figure 4 to show *s* found from two or more raw readings at least 30 mm apart (emergent ray may be extrapolated back (ruled) into outline of block) ✓	**2**
2	(a)(iii)	labelling and result for θ:	ruled normal drawn on Figure 4 where PQ meets LR; θ_1 and θ_2 correctly marked where ray enters the block with dimensions labelled on Figure 4 (condone if dimensions shown in working for 2(a)(iv); each recorded with unit, each to nearest ° or to nearest 0.5° ie 0.0° or 0.5° (don't penalise if both θ_1 and θ_2 (and θ_d) are all to 0.0°); θ_1 in range 36(.0)° to 39(.0)° ✓ (ignore angle(s) marked where ray leaves block)	1
2	(a)(iv)	result:	$\frac{s\cos\theta_2}{\sin(\theta_1-\theta_2)}$ = x_2 ± 5 mm or use outline of block if x_2 is not sensible ✓✓ [x_2 ± 10 mm ✓] (don't penalise excessive sf here; treat 2 sf answer as 3 sf with trailing zero omitted, eg treat 0.11 m as 110 mm)	**2**
2	(b)(i)	annotation to Figure 6:	sensible outline of the block marked, top edge aligned with LR to nearest mm (don't penalise again if this is the second missing outline); ruled emergent ray marked on Figure 6; emergent angle ≈ incident angle (by eye); emergent ray extrapolated (and ruled) to meet PQ ✓	**1**
2	(b)(ii)	working and result for θ_d:	precision of θ_d recorded (on answer line) to nearest ° or to nearest 0.5° and consistent with values recorded in 2(a)(iii) (don't penalise here as well as in 2(a)(iii) for inconsistent precision); θ_d in range 72(.0)° to 78(.0)° ✓	**1**
2	(c)	sketch:	internal and external rays shown ruled; TIR shown at the internal surface, angle of incidence ≈ angle of reflection (by eye); point at which TIR occurs must be below the midpoint of the block and exit point to the left of that shown for block in (b)(i); refraction away from the normal as ray leaves block $_1$✓ emergent ray <u>parallel to</u> and <u>to the left of</u> the ray in (b) $_2$✓	**2**
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Section A Task 2				
1	(a) to (c)	tabulation:	initial readings in part (a): $V_1 \geq 4.0$ V, unit to appear with at least one of V_1, V_2 or V_3; part (c) table headings: V_1/ V V_2/ V V_3/ V withhold mark for any missing unit or separator in the table headings (do not credit 'voltmeter reading' for name of variable; ignore units with data in body of table) ✓	**1**
		results:	(minimum of) 7 sets (including part (a)) of V_1, V_2 and V_3 ✓✓ deduct 1 mark for each missing set (condone (0, 0) but insist this is then plotted; deduct 1 mark if V_1 is not in the left-hand column of a single coherent table; deduct 1 mark for each set where $V_1 > V_3 > V_2$ is not true deduct 1 mark if largest (V_1) reading (in part (a)) ÷ smallest (V_2)(in table) < 10 unless $V_1 = V_2 = V_3 = 0.0$ V is tabulated maximum deduction = 2 marks	**2**
		significant figures:	all V recorded to the nearest 0.01 V or all to 0.001 V ✓ (condone all 4 dp; no interpolation allowed here)	**1**
1	(d)	axes:	marked V_3/V (vertical) and V_2/V (horizontal) ✓✓ deduct ½ for each missing label or separator, rounding down; no mark if axes are 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 should be used 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 in part (c) plotted correctly (check at least three, including any anomalous points) ✓✓✓ 1 mark is deducted for every tabulated point missing from the graph and for every point > 1 mm from correct position 1 mark is deducted if any point is poorly marked; no credit for false data	**3**
		line:	best fit line with a constant 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	**1**
		quality:	(minimum of) 7 points to ± 2mm of a suitable line as described above (judge from graph and adjust criteria if graph is poorly scaled) [if (0, 0) tabulated but not plotted, line must pass within 2 mm of origin to save Q mark] ✓	**1**
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<table>
<tr><th colspan="2">Section B</th><th colspan="2"></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
(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)</td><td>2</td></tr>
<tr><td>G no unit, in range 1.40 to 1.45 (max 4sf, reject < 3 sf) ✓✓
[1.35 to 1.50 or 1.4 ✓]
note that this is the only part of Section B where excessive sf are penalised</td><td>2</td></tr>
<tr><td>1</td><td>(b)</td><td>note that marks are awarded in (b) for (b)(iii) to (b)(v) only
<table>
<tr><th></th><th>Student's explanation</th><th>Explanation, by itself, could account for the observations stated</th></tr>
<tr><td>(b)(iii)</td><td>there is contact resistance between plug 1 and socket W</td><td>YES ✓</td></tr>
<tr><td>(b)(iv)</td><td>there is contact resistance between plug 2 and socket X</td><td>NO ✓</td></tr>
<tr><td>(b)(v)</td><td>the maximum resistance of potentiometer P is approximately 2% less than the assumed value</td><td>NO ✓</td></tr>
</table></td><td>3</td></tr>
<tr><td>1</td><td>(c)(i)</td><td>answers YES to (b)(i) or 0/1; terminal pd [V] is less than the emf [pd is dropped (accept 'lost volts' / 'energy is wasted') across the internal resistance] ✓</td><td>1</td></tr>
<tr><td>1</td><td>(c)(ii)</td><td>answers NO to (b)(ii) or 0/1; voltmeter reads zero [expected reading] (when there is no pd across it) [otherwise voltmeter would read −0.12 V / would show non-zero reading] ✓</td><td>1</td></tr>
<tr><td>1</td><td>(d)</td><td>P now acts as variable resistor [rheostat / not as potentiometer] [voltage is now shared between P and R / P and R act as a potential divider / P and R are in series] $_1$✓
smaller range (of values of V_1): this mark lost if candidate states that maximum reading lower $_2$✓
unable to produce values close to 0 V or words to that effect $_3$✓
[can still get V_1 max but not V_1 = 0 is worth $_{13}$✓✓]</td><td>MAX 2</td></tr>
</table>

2	(a)	$\sin\theta_1 = \frac{XZ}{WX}$ and $\sin\theta_2 = \frac{YZ}{WY}$ or $\frac{\sin\theta_1}{\sin\theta_2} = \frac{(XZ)\div(WX)}{(YZ)\div(WY)}$ ₁✓ (must see this step either separately or in substitution for $\frac{\sin\theta_1}{\sin\theta_2}$ or 0/2; condone *i* and *r* for θ etc) $n = \frac{(XZ)\div(WX)}{(YZ)\div(WY)} = \frac{XZ}{WX}\times\frac{WY}{YZ}$ ₂✓ $\left(= \frac{(XZ)\times(WY)}{(WX)\times(YZ)}\right)$	**2**
2	(b)	idea implied that (XZ) × (WY) = *n* × (WX) × (YZ) is of form *y* = *mx* (+ *c*); plot (XZ) × (WY) against (WX) × (YZ) [$\frac{XZ}{WX}$ against $\frac{YZ}{WY}$ etc] or 0/2 ₁✓ calculate gradient to find *n* (false plot loses both marks) ₂✓ [must mention XZ, WX, YZ and WY for full credit: bland 'plot sin θ_1 against sin θ_2 and calculate gradient to find *n*' = 1 MAX] [alternative method is to plot XZ against WX to find G_1 and plot YZ against WY to find G_2 ₁✓; evaluate $\frac{G_1}{G_2}$ to find *n* ₂✓]	**2**
2	(c)	upper limit of (XZ) range [largest value] is suitable ₁✓ largest XZ value ≈ length of block (114) [largest WX value ≈ diagonal distance (131) across block / used (approximately) largest value of XZ [WX] available] ₂✓ lower limit of (XZ or YZ) range [smallest value] is not suitable ₃✓ smallest YZ [XZ] values have large percentage uncertainty / are unreliable] ₄✓ (reject idea these values are too close to zero) smallest WX value ≈ width of block (65) ₅✓ [statement that range is suitable plus quantitative comment comparing length of block (114) with 98 (the range of XZ data) or covers more than 85% of available range] ₁₂✓✓ equivalent statement regarding WX: compares available range (131 to 65 = 66) with 63 (the range of WX data) ₁₂✓✓ = 2 MAX statement that range is suitable plus simple qualitative comment relating range to the block, eg 'a large fraction/part of the available XZ [WX] range is covered' ₁₂✓ = 1 MAX (bland 'range is large / wide' is not enough)]	**MAX 3**

3	(a)	*s* from $\frac{R_2 - R_1}{3}$ =1.43 mm ✓ (accept bald answer for 1 mark)	**1**
3	(b)	0.01 mm (condone 0.005 mm) ✓	**1**
3	(c)	uncertainty in 3*s* [in *s*] = <u>0.02</u> ✓ [2× answer for (b)] or 0/2 percentage uncertainty in 3*s* = $\frac{0.02}{4.29} \times 100 = 0.47\%$ ✓ (use of R_2 and R_1 is required; accept 1 sf 0.5%) [for precision = 0.005 mm, % uncertainty in 3*s* = $\frac{0.01}{4.29} \times 100 = 0.23\%$ ✓ (use of R_2 and R_1 is required; accept 1 sf 0.2% but reject 0.3%)	**2**
3	(d)	evidence of suitable working, eg *d* from $2s - (R_3 - R_2)$ or from $5s - (R_3 - R_1)$ or from $\frac{2(R_3 - R_1) - 5(R_2 - R_1)}{3}$ ✓ *d* = 0.84 mm ✓ [allow ecf for incorrect *s*: the candidate in (a) who evaluates the distance between the edges of adjacent holes will get *s* = 0.59 mm; they get the correct result for *d* using $\frac{R_2 - R_1}{3} - 0.59$]	**2**
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