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Physics PHA/B3X

(Specification 2450/2455)

Unit 3: Investigative and practical skills in AS Physics

Final

Mark Scheme

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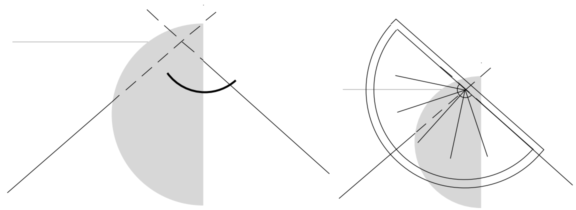
Section A Part 1				
1	(a)	accuracy:	D to the nearest mm and sensible, eg about 90 ± 30 mm ✓	**1**
1	(c)(ii)	accuracy:	θ_d to nearest ° or to nearest 0.5° (if 4 sf last figure must be '0' or '5'), value between 90° and 120° ✓	**1**
1	(c)(iii)	accuracy:	n to 3 sf, or 4 sf [condone 5 sf if final figure is (0.000)<u>5</u>], no unit, read off from horizontal scale on **Figure 5** correct to ± 0.002; result in range 1.465 to 1.535 or 3 sf values in range 1.47 to 1.53, reject '1.5' ✓✓ [1.430 to 1.570 or 3 sf values in range 1.44 to 1.46 or in range 1.54 to 1.56 ✓] (3 sf answers rounded down from 4/5 sf must be correct to actual read off to ± 0.002; if read-offs not shown on graph then 1 MAX)	**2**
1	(d)	explanation:	step E (or 0/2) ✓ emergent rays are faint / short / broaden / disperse (so uncertainty in direction is large) ✓ (reject idea uncertainty introduced in E is largest because this is the cumulative effect of all previous steps; reject 'emerging ray diffracts')	**2**
1	(e)	explanation:	details to be shown in sketch: emergent rays are extrapolated so they meet $_1$✓ (intersecting rays must be ruled; the orientation of the diagram must be as shown below left: don't insist on outline of block or line PQ) centre of the protractor <u>scale</u> positioned at the point of intersection of the emergent rays to ± 1 mm $_2$✓ (accept rays intersecting at the mid-point of the diameter or, if the drawing is poor, the rays must intersect at the point where the axial graduations on the protractor meet) rotate the protractor about the point where the rays intersect until one ray passes along a 0°/180° graduation of the protractor $_3$✓ (accept one of the emergent rays passing along the diameter of the protractor)  $_1$✓+ $_2$✓+ $_3$✓= 2 marks ✓✓ [any 2 correct points = 1 mark ✓] a mark can be awarded if the explanation clarifies a detail that is unclear in the sketch; do not award mark if explanation gives a detail that is absent from the sketch or is in conflict with what is shown	**2**

2	(a)(iii)	results and significant figures:	sets of T for m = 2, m = 3 and for m = 4, all (raw) T or nT to 0.1 s or all to 0.01 s; this mark to be withheld if m is not in the left hand column of the table, if tabulation is poor, or if T increases with m $_1$✓ values of nT (ie multiple transits) recorded for m = 2, m = 3 and for m = 4 $_2$✓ values of T or nT repeated for m = 2, m = 3 and for m = 4 $_3$✓	**3**
2	(b)(i)	analysis:	3 values of $T\sqrt{m}$ correctly calculated (allow T^2m) or 0/2, all results to same sf as (mean) T data (or mean T data with least sf) $_1$✓ statement that k = constant so theory is correct providing largest k ÷ smallest $k \leq 1.08$ $_2$✓ [statement that k = not constant [trend apparent, eg as m increases k increases] so theory is incorrect providing largest k ÷ smallest $k \geq 1.05$; accept either statement as correct if k is between 1.05 and 1.08 ✓]	**2**
2	(b)(ii)	relevant observation about the shape of the tray:	the cross-sectional area of the tray is constant / does not vary (with depth) [the walls [sides] of the tray are vertical] $_{1A}$✓ (reject ‘shape changes’ and reject tray is rectangular’ unless qualified by adding ‘in all three dimensions’) or the cross-sectional area of the tray is not constant / does vary (with depth) [the walls [sides] of the tray are not vertical / slope [slant] outwards / the bottom of the tray is not flat] $_{1B}$✓] [accept use of relevant dimensions of the tray (not the depth of water in it) to make either of these points $_1$✓]	**1**
		explanation about whether $m \propto$ depth:	(if claiming constant CSA) the assumption is correct because doubling m [volume] doubles depth / rate of change of m is the same as the rate of change of depth [adding 1 measure produces the same increase in depth] $_{2A}$✓ or (if claiming variation in CSA or using the idea that the bottom of tray is not flat) the assumption is not correct because doubling m [volume] does not double depth etc [as m increases, depth increases at a decreasing rate / need bigger measures to produce same increase in depth] $_{2B}$✓]	**1**
		alternative approach:	for m = 1 the water did not completely cover the base (due to surface tension) $_{1C}$✓ so assumption is not correct because the depth is not constant $_{2C}$✓]	
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Section A Part 2				
1	(a)	accuracy:	*d* recorded to 0.01mm (expect ≈ 0.37 mm) for analogue micrometer (condone 0.001 mm for digital micrometer providing this is consistent with candidate's data) from *nd* where $\Sigma n \geq 3$ ✓	**1**
1	(b)	tabulation:	*m* / g *l* / mm $\sqrt{m}$ (/$g^{\frac{1}{2}}$) ✓✓ accept other valid unit, kg, m; deduct ½ for each missing label or separator, rounding down	**2**
		results:	6 sets of *m* and *l* ✓✓ deduct 1 mark for each missing set, if *m* range < 300 g and if *m*/ g is not in the left-hand column (max deduction 2 marks)	**2**
		significant figures:	all (raw) *l* to nearest mm; all *m* to nearest g ✓ all $\sqrt{m}$ to 3 sf ✓ (tolerate all to 4 sf)	**2**
1	(c)	axes:	marked *l*/mm, $\sqrt{m}$ /$g^{\frac{1}{2}}$ $\left[kg^{\frac{1}{2}}\right]$ (condone $\sqrt{kg}$) ✓✓ deduct ½ for each missing label or separator, rounding down; [bald *l*(vertical) and $\sqrt{m}$ (horizontal) ✓]; 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 ✓ and 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 or non-linear scale; deduct 1 mark if one or both axes have the origin incorrectly marked	**2**
		points:	6 points 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 deduct 1 mark if any point is poorly marked; no credit for false data	**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	**1**
		quality:	at least 5 points to ± 2mm of a suitable line of positive constant gradient (judge from graph and adjust criteria if graph is poorly scaled) ✓	**1**
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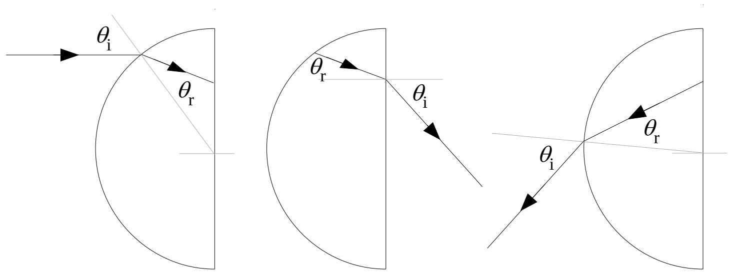
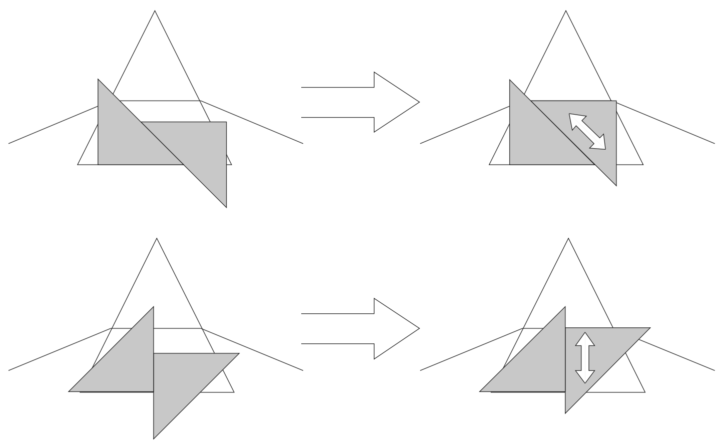
Section B			
1	(a)(i)	valid attempt at gradient calculation and correct transfer of data **or** $_{12}$✓**= 0** correct transfer of *y*- and *x*-step data between graph and calculation $_1$✓ (mark is withheld if points used to determine either step > 1 mm from correct position on grid; if tabulated points 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)	**2**
1	(a)(ii)	μ in range 0.82 to 1.10 × 10^{-3} or 0.9 or 1.0 × 10^{-3} kg m^{-1} ✓✓ [0.67 to 1.25 × 10^{-3} or 0.8, 1.1, 1.2 × 10^{-3} kg m^{-1} ✓] withhold 1 mark for missing or incorrect unit	**2**
1	(b)(i)	<u>valid</u> deduction that the wire is 28 SWG; check with part (a) of Section A Part 2 to confirm ✓	**1**
1	(b)(ii)	*d* is larger [cross-sectional) <u>area</u> / thickness is larger] $_1$✓ μ is larger (reject 'mass larger') $_2$✓ *G* is smaller $_3$✓ [*G* larger for *d* smaller and μ smaller, $_{123}$✓]	**3**
1	(c)(i)	0.5 mm (must be a valid unit with answer) ✓	**1**
1	(c)(ii)	any sensible answer describing possible consequences of use of the thimble e.g., can cause the object being measured to be distorted, crushed or wtte; the frame of the micrometer might become warped or damage might occur to the screw thread mechanism; may lead to the reading shown being <u>smaller</u> than true value ✓ (reject 'might change the reading' / 'affect results', 'cause reading below zero', 'could lead to systematic error' or bland 'over-tighten'; ignore explanations that refer to closing the micrometer using the ratchet)	**1**
1	(c)(iii)	(close jaws of micrometer using ratchet and) check for <u>zero error</u> ✓ (if the exact phrase is not used, allow a valid description of how this would be done, e.g. 'close the jaws and check the reading shown is zero'; reject 'measure an object of known thickness and compare' or 'compare with reading produced by another instrument')	**1**
1	(c)(iv)	repeat reading at <u>different point</u>(s) [different orientations] on wire and <u>calculate an average</u> value for *d* [repeat reading at <u>different point</u>(s) on wire and check for any anomalous reading / ensure the results were consistent] ✓	**1**

2	(a)(i)	<u>both</u> internal rays correctly shown ✓	**1**
2	(a)(ii)	two relevant angles marked (or 0/2) between a suitable* ruled normal and the directions of the incident (or either emergent) ray in **Figure 9**, and the direction of a correct internal ray; the angles must be clearly distinguished by appropriate labels, e.g. θ_i, θ_r (see below) $_1$✓  *n* calculated from $\frac{\sin\theta_i}{\sin\theta_r}$; no ecf for non-relevant angles or if a freehand normal is drawn but allow this mark for an imperfect† ruled normal $_2$✓ * a suitable normal is defined as follows: the normal where the incident ray reaches the block must reach the diameter by ≤ 2 mm from its intersection with PQ; the normal to the diameter must be parallel to PQ (by eye); if in doubt, extrapolate so normal is same length as PQ then check distance from each end of normal to points P and Q (max discrepancy 1 mm) the normal where the ray emerges from the curved face must reach the diameter by ≤ 1 mm from its intersection with PQ) † an imperfect normal is defined as follows: the normal where the incident ray reaches the block must reach the diameter by ≤ 5 mm from its intersection with PQ; the normal to the diameter must be parallel to PQ (by eye); if in doubt, extrapolate so normal is same length as PQ then check distance from each end of normal to points P and Q (max discrepancy 2 mm) the normal where the ray emerges from the curved face must reach the diameter by ≤ 2 mm from its intersection with PQ)	**2**
2	(b)	(angular) measurement made in Section A Part 1 method is (much) larger than (smaller) measurement(s) made in alternative method ✓ so <u>percentage</u> uncertainty (in measurement of the angle θ_d and hence in the result for *n*) is smaller ✓	**2**

3	(a)	methods involving 2 suitable linear measurements can earn 2 marks; measure distance x_1 between point at which incident ray enters the prism and bottom left corner [or apex] and distance x_2 between point at which emergent ray leaves the prism and bottom right corner [or apex] $_1$✓ check these distances are equal (and if not, adjust position of block until this is the case) $_2$✓ [extrapolate incident and emergent rays to the extrapolated baseline of the prism and measure these distance to the left and right apexes $_1$✓; check these distances are equal $_2$✓ extrapolate internal ray and the baseline of the prism on both sides then measure the <u>perpendicular</u> distance between (well-separated) points on these two lines $_1$✓ check these distances are equal $_2$✓]	2
		[weaker method can earn 1 mark measure <u>perpendicular</u> distance x_1 between <u>point</u> at which incident ray enters the prism and base of prism, and the corresponding <u>perpendicular</u> distance x_2 between <u>point</u> at which incident ray leaves the prism and base of prism; check these distances are equal $_{12}$✓]	
		[methods involving 2 suitable angular measurements can earn 1 mark measure angle θ_1 between incident ray and face of prism and angle θ_2 between emergent ray and face of prism (must be equivalent angles); check these angles are equal $_{12}$✓ measure angle between incident ray and normal to prism, and between emergent ray and normal to prism; check these are equal $_{12}$✓ extrapolate emergent ray and measure the angle between this and incident ray; check this is equal to angle of deviation $_{12}$✓ measure angle between internal ray and face of prism at both sides and check these angles are equal $_{12}$✓]	
		[other novel methods can earn 2 marks, e.g. use of <u>two</u> set-squares position a set-square with a shorter edge aligned with the base of the prism; place another set-square in contact with the first then slide this in the manner shown below $_1$✓  check the alignment of a relevant edge (which must be parallel with the base of the prism) against the direction of the internal ray $_2$✓]	

3	(b)	percentage uncertainty in θ_d = $\frac{2}{40} \times 100 = 5\%$ ✓	**1**
3	(c)(i)	$n = \sqrt{3}\,\sin\left(\frac{38}{2}\right) + \cos\left(\frac{38}{2}\right)$ = 1.51 [1.509] ✓	**1**
3	(c)(ii)	$n = \sqrt{3}\,\sin\left(\frac{42}{2}\right) + \cos\left(\frac{42}{2}\right)$ = 1.55 [1.554 if (c)(i) = 1.509] ✓ sf for (c) must be consistent and appropriate i.e. both to 3sf or both to 4sf or deduct 1 mark	**1**
3	(c)(iii)	uncertainty in *n* = ½ range (or 0/2); same dp as for (c)(i) and (c)(ii) (or deduct mark unless already deducted for inconsistent sf for (i) and (ii)) $_1$✓ percentage uncertainty in *n* = $\frac{\text{uncertainty in } n}{1.53} \times 100$ $_2$✓ (allow ecf for wrong min or max *n*; tolerate 4 sf if this rounds to 3 sf value shown in bottom row below, but reject 2 sf)	**2**
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		5sf	4sf	3sf	2sf
(c)(i)	min *n*	1.5094	1.509	1.51	1.5
(c)(ii)	max *n*	1.5543	1.554	1.55	1.6
(c)(iii)	Δn	0.0225 [allow 0.023]	0.023	0.02	allow 0.05
	% uncertainty	1.47(%) [allow 4 sf]	1.50(%)	1.31(%)	3.27(%) [allow 4 sf]