



**General Certificate of Education (A-level)
June 2013**

Physics

PHA/B3X

(Specification 2450/2455)

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

Final

Mark Scheme

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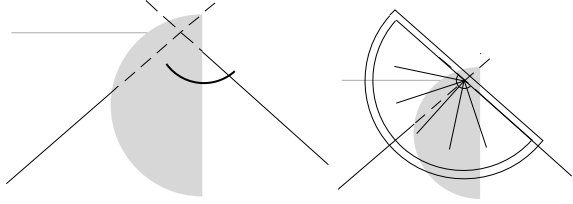
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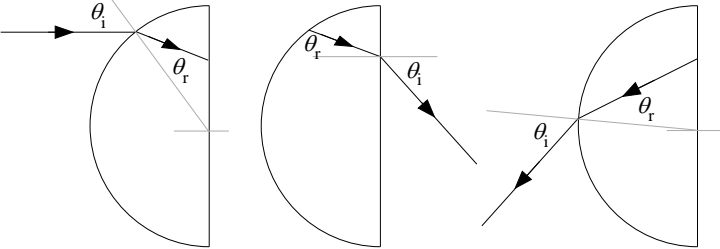
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Section A Part 1				
1	(a)	accuracy:	D to the nearest mm and sensible, eg about 90 ± 30 mm ✓	1
1	(c)(ii)	accuracy:	θ_d to nearest $^\circ$ or to nearest 0.5° (if 4 sf last figure must be '0' or '5'), value between 90° and 120° ✓	1
1	(c)(iii)	accuracy:	<p>n to 3 sf, or 4 sf [condone 5 sf if final figure is (0.000)5], 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' ✓✓</p> <p>[1.430 to 1.570 or 3 sf values in range 1.44 to 1.46 or in range 1.54 to 1.56 ✓]</p> <p>(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)</p>	2
1	(d)	explanation:	<p>step E (or 0/2) ✓</p> <p>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')</p>	2
1	(e)	explanation:	<p>details to be shown in sketch:</p> <p>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)</p> <p>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)</p> <p>rotate the protractor about the point where the rays intersect until one ray passes along a $0^\circ/180^\circ$ graduation of the protractor $_3$✓ (accept one of the emergent rays passing along the diameter of the protractor)</p>  <p>$_1$✓ + $_2$✓ + $_3$✓ = 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</p>	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 $_1\checkmark$ values of nT (ie multiple transits) recorded for $m = 2$, $m = 3$ and for $m = 4$ $_2\checkmark$ values of T or nT repeated for $m = 2$, $m = 3$ and for $m = 4$ $_3\checkmark$	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) $_1\checkmark$ statement that $k = \text{constant}$ so theory is correct providing largest $k \div \text{smallest } k \leq 1.08$ $_2\checkmark$ [statement that $k = \text{not constant}$ [trend apparent, eg as m increases k increases] so theory is incorrect providing largest $k \div \text{smallest } k \geq 1.05$; accept either statement as correct if k is between 1.05 and 1.08 \checkmark]	2
2	(b)(ii)	relevant observation about the <u>shape</u> of the tray:	the <u>cross-sectional</u> area of the tray is constant / does not vary (with depth) [the walls [sides] of the tray are vertical] $_{1A}\checkmark$ (reject 'shape changes' and reject tray is rectangular' unless qualified by adding 'in all three dimensions') or the <u>cross-sectional</u> 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] $_{1B}\checkmark$ [accept use of relevant dimensions of the tray (not the depth of water in it) to make either of these points $_1\checkmark$]	1
		explanation about whether $m \propto \text{depth}$:	(if claiming constant CSA) the assumption is correct <u>because</u> 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] $_{2A}\checkmark$ or (if claiming variation in CSA or using the idea that the bottom of tray is not flat) the assumption is not correct <u>because</u> 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] $_{2B}\checkmark$	1
		alternative approach:	for $m = 1$ the water did not completely cover the base (due to surface tension) $_{1C}\checkmark$ so assumption is not correct because the depth is not constant $_{2C}\checkmark$	
				15

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 , $\sqrt{m}/g^{\frac{1}{2}} [kg^{\frac{1}{2}}]$ (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 ✓ <u>and</u> 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 ± 2 mm of a suitable line of positive constant gradient (judge from graph and adjust criteria if graph is poorly scaled) ✓	1
				16

Section B			
1	(a)(i)	valid attempt at gradient calculation and correct transfer of data or $_{12}\checkmark = 0$ correct transfer of y - and x -step data between graph and calculation $_1\checkmark$ (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 $_2\checkmark$ (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 $1.0 \times 10^{-3} \text{ kg m}^{-1}$ $\checkmark\checkmark$ $[0.67$ to 1.25×10^{-3} or $0.8, 1.1, 1.2 \times 10^{-3} \text{ kg m}^{-1}$ $\checkmark]$ 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 \checkmark	1
1	(b)(ii)	d is larger [cross-sectional) <u>area</u> / thickness is larger] $_1\checkmark$ μ is larger (reject 'mass larger') $_2\checkmark$ G is smaller $_3\checkmark$ $[G$ larger for d smaller and μ smaller, $_{123}\checkmark]$	3
1	(c)(i)	0.5 mm (must be a valid unit with answer) \checkmark	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 \checkmark (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> \checkmark (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(s)</u> [different orientations] on wire and <u>calculate an average</u> value for d [repeat reading at <u>different point(s)</u> on wire and check for any anomalous reading / ensure the results were consistent] \checkmark	1

2	(a)(i)	<u>both</u> internal rays correctly shown ✓	1
2	(a)(ii)	<p>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✓</p>  <p>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✓</p> <p>* 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)</p> <p>[†] 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)</p>	2
2	(b)	<p>(angular) measurement made in Section A Part 1 method is (much) larger than (smaller) measurement(s) made in alternative method ✓</p> <p>so <u>percentage</u> uncertainty (in measurement of the angle θ_d and hence in the result for n) is smaller ✓</p>	2

3	(a)	<p>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] $_1\checkmark$ check these distances are equal (and if not, adjust position of block until this is the case) $_2\checkmark$ [extrapolate incident and emergent rays to the extrapolated baseline of the prism and measure these distance to the left and right apexes $_1\checkmark$; check these distances are equal $_2\checkmark$ 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 $_1\checkmark$ check these distances are equal $_2\checkmark$]</p> <p>[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 $_2\checkmark$]</p> <p>[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 $_2\checkmark$ measure angle between incident ray and normal to prism, and between emergent ray and normal to prism; check these are equal $_2\checkmark$ extrapolate emergent ray and measure the angle between this and incident ray; check this is equal to angle of deviation $_2\checkmark$ measure angle between internal ray and face of prism at both sides and check these angles are equal $_2\checkmark$]</p> <p>[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 $_1\checkmark$</p> <div style="text-align: center;"> </div> <p>check the alignment of a relevant edge (which must be parallel with the base of the prism) against the direction of the internal ray $_2\checkmark$]</p>	2
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3	(b)	percentage uncertainty in $\theta_d = \frac{2}{40} \times 100 = 5\% \checkmark$	1																													
3	(c)(i)	$n = \sqrt{3} \sin\left(\frac{38}{2}\right) + \cos\left(\frac{38}{2}\right) = 1.51 [1.509] \checkmark$	1																													
3	(c)(ii)	$n = \sqrt{3} \sin\left(\frac{42}{2}\right) + \cos\left(\frac{42}{2}\right) = 1.55 [1.554 \text{ if } (c)(i) = 1.509] \checkmark$ 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)	<p>uncertainty in $n = \frac{1}{2}$ 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✓</p> <p>percentage uncertainty in $n = \frac{\text{uncertainty in } n}{1.53} \times 100$ ₂✓</p> <p>(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)</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th></th> <th></th> <th>5sf</th> <th>4sf</th> <th>3sf</th> <th>2sf</th> </tr> </thead> <tbody> <tr> <td>(c)(i)</td> <td>min n</td> <td>1.5094</td> <td>1.509</td> <td>1.51</td> <td>1.5</td> </tr> <tr> <td>(c)(ii)</td> <td>max n</td> <td>1.5543</td> <td>1.554</td> <td>1.55</td> <td>1.6</td> </tr> <tr> <td rowspan="2">(c)(iii)</td> <td>Δn</td> <td>0.0225 [allow 0.023]</td> <td>0.023</td> <td>0.02</td> <td>allow 0.05</td> </tr> <tr> <td>% uncertainty</td> <td>1.47(%) [allow 4 sf]</td> <td>1.50(%)</td> <td>1.31(%)</td> <td>3.27(%) [allow 4 sf]</td> </tr> </tbody> </table>			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]	2
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