Version 1.0

General Certificate of Education
June 2010

Physics PHA3/B3/X

Investigative and Practical Skills in AS Physics

Unit 3

Final

Mark Scheme

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

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

Section A, Task 1

Question 1			
(a) (i)/(ii)	accuracy	y_1 and y_2 recorded to 1 mm, $y_2 - y_1$ in range 375 mm to 425 mm ✓	**1**
(b) (i)/(ii)	accuracy & method	(raw readings of) x_G and x_R recorded to 0.1 cm, $x_G < x_R$, values sensible ✓	**1**
	method	some evidence must be shown of repeated readings (eg to the left and to the right of central (undeviated) image of slit, or determination of the position of the centre of a fringe position by reading to the inside and to the outside of the image of the slit) ✓	**1**
(c)	accuracy	θ_G and θ_R calculated from = θ $\tan^{-1}\left(\frac{x}{y_2-y_1}\right)$, $\theta_G < \theta_R$, values in the range 8.0° to 12.0° ✓ (accept 2, 3 or 4 sf)	**1**
		$\frac{sin\theta_R}{sin\theta_G}$, no unit, in range 1.11 to 1.23 ✓✓ [1.05 to 1.10 or 1.24 to 1.28, 1.1 or 1.2 ✓] (allow $\frac{sin\theta_R}{sin\theta_G} = \frac{x_R}{x_G}$)	**2**
(d)	explanation	(illuminate the grating, ie reject Young's slits method) using **monochromatic** light [accept 'use a laser'] ✓ (reject bland 'red' or 'green')	**1**
		the **wavelength** [frequency] of the light should be known ✓ [use same (monochromatic) source to illuminate a grating with known **spacing**, d_k; measure diffraction angle, θ_k ✓]	**1**
		find d from $\frac{(n)\lambda}{sin\theta}$ ['use $n\lambda = d \sin\theta$'] ✓ [$d_u = d_k \frac{sin\theta_k}{sin\theta_u}$ ✓]	**1**
		measure θ directly using a spectrometer [large protractor] ✓ determine θ by measuring across several orders, ie n > 1 or by measuring θ to the left and to the right, ie 2θ and divide result by 2 ✓ increase distance between **grating and screen** [slit] ✓ use source with large λ (to increase θ) ✓ repeat experiment using another light source of **different** known λ to obtain average result for d ✓ perform experiment in a dark room ✓ (reject 'repeat/take multiple readings of θ and average' or 'use a more precise scale')	**max 1**
		Total	**10**

Question 2				
(a)	(i)/ (ii)	observations and method	**raw readings** for *p* and *D* must each be to the nearest mm; working to show that *p* is found from *np* where *n* or $\Sigma n \geq 10$ ✓	1
	(iii)	accuracy	$\frac{D}{p}$, no unit, in range 9.1 to 10.0 ✓✓ [8.6 to 9.0 or 10.1 to 10.5 or 10 ✓]	2
(b)		explanation	the sf for $\frac{D}{p}$ must be the same as the (minimum) sf used in the (calculated) values of *D* and *p* ✓ (accept 'same sf used in the measurements'; reject '1 more sf than in data')	1
			Total	**4**

Section A Task 2

Question 1			
(a)	accuracy	h_0 to nearest mm, value sensible (700 mm to 950 mm) ✓ (any $(h_0 - h)$ set < 0 loses this mark)	1
(b)	tabulation	*x* /mm *h* /mm $(h_0 - h)$ (/*mm*) ✓✓ deduct ½ for each missing label or separator, rounding down; penalise if *x*/mm is not in the left-hand column of the table	2
	results	6 sets of *x* and *h*; initial *x* = 900 mm ✓ (reject '0, 0') 4 sets for $x \geq 500$ mm; *x* range ≥ 400 mm ✓	2
	significant figures	all *x* and all *h*, including h_0, to nearest mm ✓	1
	quality	all 6 points to ± 2mm of suitable line, positive gradient (judge from graph; adjust criterion if graph is poorly-scaled)✓	1
(c)	axes	marked $(h_0 - h)$/mm (vertical) and *x*/mm (horizontal) ✓✓ deduct ½ for each missing label or separator, rounding down; no mark if axes reversed; (award **1 max** for $(h_0 - h)$ and *x*)	2
	scales	points should cover at least half the grid horizontally ✓ **and** 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 or if the interval between the numerical values are marked on an axis with a frequency of > 5 cm)	2
	points	all tabulated points plotted correctly; minimum of 6 points (check at least three including every anomalous point) ✓✓✓ 1 mark is deducted for every tabulated point not plotted, for every point > 1 mm from correct position and if any point is poorly marked; 5 points = **2 max**, 4 points = **1 max** there is no credit for false data	3
	line	best fit line of positive, **continuously increasing** gradient ✓ maximum acceptable deviation from best fit line is 2 mm (adjust criterion if graph is poorly-scaled); any point of inflexion loses this mark (tolerate no more than one straight link between adjacent points); there is no credit for false data	1
		Total	**15**

Section B

Question 1		
(a)	method: evidence that a tangent, or a line parallel to the tangent (accept a chord), or a normal has been drawn to the curve where x = 650 **and** where x = 750 (accept any of these as the hypotenuse of Δ) ✓ y-step at least 8 cm and x-step at least 8 cm [tolerate 13 cm × 5 cm or 5 cm × 13 cm] (apply to the larger of the two triangles) ✓ correct transfer of y- and x-step data between graph and different calculations of G_1 and of G_2 ✓ (mark is withheld if points used to determine either step > 1 mm from correct position on grid; penalise for x, y data with mixed units) [gradient calculations based on incorrect methods: $G = \Delta x/\Delta y$ cannot earn $_3\Delta$ ie 2/3 max; a straight line graph can only earn $_2\Delta$, ie 1/3 max; $G = \tan\theta$ gets no credit, ie 0/3 max]	**3**
(b)	$\frac{G_1}{G_2}$, no unit, in range 1.64 to 1.91, 1.7 or 1.8 ✓✓ [1.51 to 1.63 or 1.92 to 2.04, 1.6, 1.9 or 2.0 ✓] (results based on $G = \Delta x/\Delta y$ or $G = \tan\theta$ can gain no credit)	**2**
(c)	(use of mirror to) construct the **normal** [or clear description of process; place mirror across curve and rotate mirror until curve and reflection are continuous] (from which the gradient can be determined) ✓ [(use of mirror to) construct the **tangent**; [or clear description of process; arrange mirror so that curve and reflection are equidistant from (front of) mirror] ✓] expect to find evidence on the grid that the claim being made is valid, or withhold this mark	**1**
	Total	**6**

Question 2		
(a)	sketch or clear description of wooden ruler made vertical by use of **set-square** ✓ on two (mutually perpendicular) sides of the ruler ✓ (both marks may be awarded for suitable sketch)	**2**
(b)	vertical scale placed (close) behind pin and mirror placed (close) behind, and parallel to, the scale (do not insist on mirror in contact with the scale); the arrangement should be such that the mirror and vertical scale are parallel to the edge of the bench (do not award this mark unless the arrangement is clear) ✓ apparatus viewed so that pin hides its own reflection [pin and reflection are horizontally aligned] ✓ (these marks may be awarded for suitable sketch) this avoids **parallax** error ✓	**3**
	Total	**5**

<table>
<tr><td>Question 3</td><td></td><td></td></tr>
<tr><td>(a)</td><td>
D could not be measured with enough precision; [can only resolve to 1 sf/2 dp (and 3 sf/4 dp needed)/needs to measure to 0.0001 mm] ✓
example given to correctly illustrate this point, eg 0.0855 mm would be read as 0.09 mm ✓

same D would be produced for different α ✓
example given to correctly illustrate this point, eg when α = 12°/14°/16° ✓

there would be a large percentage uncertainty [percentage error] in D ✓
example given to correctly illustrate this point, eg when α = 8° percentage uncertainty is 47% ✓ (tolerate answers using ΔD = 0.01 mm or 0.02 mm)

<table>
<tr><td rowspan="2">α/°</td><td colspan="2">D/mm</td><td rowspan="2">% uncertainty (ΔD = 0.01 mm)</td></tr>
<tr><td>spreadsheet</td><td>to 0.01 mm</td></tr>
<tr><td>2</td><td>0.0855</td><td>0.09</td><td>11.7%</td></tr>
<tr><td>4</td><td>0.0428</td><td>0.04</td><td>23.4%</td></tr>
<tr><td>6</td><td>0.0285</td><td>0.03</td><td>35.1%</td></tr>
<tr><td>8</td><td>0.0214</td><td>0.02</td><td>46.8%</td></tr>
<tr><td>10</td><td>0.0171</td><td>0.02</td><td>58.5%</td></tr>
<tr><td>12</td><td>0.0143</td><td>0.01</td><td>70.2%</td></tr>
<tr><td>14</td><td>0.0122</td><td>0.01</td><td>81.9%</td></tr>
<tr><td>16</td><td>0.0107</td><td>0.01</td><td>93.6%</td></tr>
</table>
</td><td>max 4</td></tr>
<tr><td>(b)</td><td>argument is not sensible because (larger value of D leads to) very small values of α ✓
(hence) α cannot be measured accurately [uncertainty would be very large] ✓</td><td>2</td></tr>
<tr><td>(c)</td><td>$\frac{0.0859-0.0855}{0.0859}$ × 100 ✓ (working must show 0.0859 in denominator, or 0/2)

= 0.466% or 0.47% only ✓ (ie 0.5% is worth 1 max)</td><td>2</td></tr>
<tr><td></td><td>Total</td><td>8</td></tr>
</table>

Question 4		
(a)	$_1$M mass measured on a balance (accept 'scales') ✓ $_2$M *l* found by measuring with a ruler [mm scale, tape measure] ✓ $_3$M *d* found by using a ruler [vernier scale/travelling microscope] ✓ $_1$S apply tensile force by attaching masse(s) to (lower end of) strip (accept 'attach weight(s)' or 'use newton meter' but $_1$M = $_2$S = 0) ✓ $_2$S (tensile) force found by multiplying mass by *g* [9.81] ✓ $_3$S **calculate** Δ*l* for **different** *F* or $_{45}$S = 0 ✓ $_4$S plot a graph of *F* against Δ*l* or $_5$S = 0 ✓ $_5$S find stiffness of the strip of transparent sheet by measuring the gradient ✓ [accept reverse argument, ie plot Δ*l* against *F* and measure (gradient)$^{-1}$] [alt: $_3$S **measure** *d* for **different** *F* or $_{45}$S = 0 ✓; $_4$S plot a graph of *F* against d^{-1} or $_5$S = 0 ✓; $_5$S measure the gradient; stiffness = 2*G*/*pL* ✓ $_1$P check that balance is tared beforehand ✓ $_2$P using a long strip [large masses/weights] reduces the error in *l* ✓ $_3$P measuring **across multiple fringes** and divide by number of fringe widths; reject bland 'repeat and average' ✓	**max 6**
(b)	(idea that) the extension produced is too small (to cause a significant change in *d*) [masses required would be too large, accept 'will not stretch (easily)'] ✓	**1**
	Total	**7**