

CAMBRIDGE INTERNATIONAL EXAMINATIONS

Cambridge International Advanced Subsidiary and Advanced Level

MARK SCHEME for the May/June 2015 series

9702 PHYSICS

9702/31

Paper 1 (Advanced Practical Skills 1),
maximum raw mark 40

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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Page 2	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	31

- 1 (a) (ii) Value of w with unit, in range 45.0 cm to 55.0 cm. [1]
- (c) (iii) Value of I_B , with unit, to nearest 0.1 mA, in range $70.0 \leq I_B \leq 100.0$ mA. [1]
- (d) Six sets of readings of w , I_A and I_B , different values, scores 5 marks, five sets scores 4 marks, etc. [5]
 Incorrect trend –1.
 Major help from Supervisor –2. Minor help from Supervisor –1.
- Range: [1]
 Range of $w \geq 60.0$ cm.
- Column headings: [1]
 Each column heading must contain a quantity and a unit.
 The presentation of quantity and unit must conform to accepted scientific convention e.g. w/cm , $w(\text{cm})$, $(I_A+I_B)/(I_AI_B)/A^{-1}$, $(I_A+I_B)/(I_AI_B)/(1/A)$.
 Do not allow $(I_A+I_B)/(I_AI_B)/(A/A^2)$.
- Consistency: [1]
 All values of w must be given to the nearest mm only.
- Significant figures: [1]
 Every value of $(I_A+I_B)/(I_AI_B)$ must be given to the same number of s.f. as (or one more than) the least s.f. in the corresponding values of I_A and I_B .
- Calculated values: [1]
 Values of $(I_A+I_B)/(I_AI_B)$ calculated correctly to the number of significant figures given by the candidate.
- (e) (i) Axes: [1]
 Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.
 Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions.
 Scales must be labelled with the quantity that is being plotted.
 Scale markings should be no more than three large squares apart.
- Plotting of points: [1]
 All observations in the table must be plotted.
 Diameter of points must be $\leq$ half a small square (no “blobs”).
 Plotted points must be accurate to within half a small square.
- Quality: [1]
 All points in the table must be plotted on the grid (at least 5) for this mark to be awarded.
 All points must be within ± 5 cm (± 0.05 m) on the w -axis from a straight line.
- (ii) Line of best fit: [1]
 Judge by balance of all points on the grid about the candidate's line (at least 5 points). There must be an even distribution of points either side of the line along the full length.
 Allow one anomalous point only if clearly indicated by the candidate.
 Lines must not be kinked or thicker than half a square.

Page 3	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	31

- (iii) Gradient: [1]
 The hypotenuse of the triangle must be greater than half the length of the drawn line.
 The method of calculation must be correct.
 Both read-offs must be accurate to half a small square in both the x and y directions.

y -intercept: [1]
 Either:
 Correct read-offs from a point on the line and substituted into $y = mx + c$.
 Read-off must be accurate to half a small square in both x and y directions.
 Or:
 Check read-off of the intercept directly from the graph
 (accurate to half a small square).

- (f) M = value of the candidate's gradient and N = value of the candidate's y -intercept. [1]
 Do not allow substitution methods. Do not allow fractions.

Unit for M correct (e.g. $A^{-1} m^{-1}$ or $A^{-1} cm^{-1}$ or $A^{-1} mm^{-1}$ or $mA^{-1} m^{-1}$ or $mA^{-1} cm^{-1}$ or $mA^{-1} mm^{-1}$)
 and unit for N correct (e.g. mA^{-1} or A^{-1}). [1]

- 2 (a) (i) Value of L with unit, in range $55.0\text{ cm} \leq L \leq 65.0\text{ cm}$. [1]

- (ii) Value of m to nearest gram or better, in range $10.0\text{ g} \leq m \leq 100.0\text{ g}$. [1]

- (iv) Correct justification of significant figures in p linked to significant figures in L and m . [1]

- (b) (i) Value of M to the nearest gram or better, in range $90.0\text{ g} \leq M \leq 110.0\text{ g}$. [1]

- (iii) Correct calculation of C . [1]

- (c) (ii) Value of x to the nearest mm, with unit, in range $5.0\text{ cm} \leq x \leq 20.0\text{ cm}$. [1]

- (iii) Absolute uncertainty in x in range $2 - 5\text{ mm}$.
 If repeated readings have been taken, then the uncertainty can be half the range (but not zero) if the working is clearly shown.
 Correct method of calculation to obtain percentage uncertainty. [1]

- (d) Second value of L . [1]

Second value of x . [1]

Correct trend for x with respect to L (x decreases as L decreases). [1]

- (e) (i) Two values of k calculated correctly. [1]

- (ii) Valid comment consistent with calculated values of k , testing against a criterion specified by the candidate. [1]

Page 4	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	31

(f)	(i) Limitations (4 max.)	(ii) Improvements (4 max.)	Do not credit
A	Two readings not enough to draw a valid <u>conclusion</u> .	Take more readings (for different L) <u>and</u> plot a graph/ take more readings <u>and</u> compare k values.	“repeat readings”/ “too few readings”
B	Difficult to measure x with reason, e.g. parallax/ruler not in line with wood/strip moves as touched while taking measurement/mass obscures end of rule/strip oscillates/balance achieved for a short time	Improved method to measure x e.g. attach mass to bottom of strip/mark scale on strip/mark strip at balance point/measure $(L-x)$ /clamp ruler <u>horizontally</u>	Travelling microscope Video
C	Difficult to balance with reason, e.g. wind/air conditioning or pivot moves	Method to remove wind, e.g. turn off fans/close windows or method of fixing pivot to bench i.e. tape/heavier pivot	Sliding rule Pivot size
D	Problem with Blu-Tack, e.g. mass of Blu-Tack not taken into account	Method to overcome problem with Blu-Tack, e.g. measure mass of Blu-Tack <u>and</u> add to value of M or fix mass with named adhesive, e.g. tape/glue <u>because this has less mass</u>	
E	Difficult to know where centre of mass is with reason, e.g. slot in mass or Difficult to place centre of mass at end of strip	Detailed method of finding centre of mass Method to attach mass on strip to ensure centre of mass is at the end of strip, e.g. hang mass from strip with thread	Mark centre of mass Measure diameter
F	Two strips have different density/ ρ	Find mass or ρ of second strip	Different thickness/cross-sectional area

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MARK SCHEME for the May/June 2015 series

9702 PHYSICS

9702/32

Paper 3 (Advanced Practical Skills 2),
maximum raw mark 40

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Page 2	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	32

- 1 (c) (ii) Value of h in the range 45.0 to 55.0 cm. [1]
- (iii) Value of x less than 50.0 cm. [1]
- (d) Six sets of readings of x and h scores 5 marks, five sets scores 4 marks etc. [5]
 Incorrect trend –1. Help from Supervisor –1.
- Range: [1]
 $x_{\max} - x_{\min} \geq 60.0$ cm.
- Column headings: [1]
 Each column heading must contain a quantity and a unit where appropriate. The presentation of quantity and unit must conform to accepted scientific convention. e.g. $1/h/\text{cm}^{-1}$. x/h must have no unit.
- Consistency: [1]
 All values of h and all values of x must be given to the nearest mm.
- Significant figures: [1]
 Every value of x/h must be given to the same number of s.f. (or one more than) the least number of s.f. in the corresponding values of x and h as recorded in table.
- Calculation: [1]
 Values of x/h calculated correctly.
- (e) (i) Axes: [1]
 Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.
 Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions.
 Scales must be labelled with the quantity that is being plotted.
 Scale markings should be no more than three large squares apart.
- Plotting: [1]
 All observations must be plotted on the grid. Diameter of plotted points must be $\leq$ half a small square (no “blobs”).
 Plotted points must be accurate to within half a small square in both x and y directions.
- Quality: [1]
 All points in the table must be plotted (at least 5) for this mark to be awarded.
 Scatter of points must be no more than ± 0.1 from a straight line in the x/h direction.
- (ii) Line of best fit: [1]
 Judge by balance of all points on the grid about the candidate’s line (at least 5 points). There must be an even distribution of points either side of the line along the full length.
 Allow one anomalous point only if clearly indicated (i.e. circled or labelled) by the candidate.
 Lines must not be kinked or thicker than half a square.

Page 3	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	32

- (iii) Gradient: [1]
 The hypotenuse of the triangle must be greater than half the length of the drawn line.
 The method of calculation must be correct.
 Both read-offs must be accurate to half a small square in both the x and y directions.

y -intercept: [1]
 Either:
 Correct read-offs from a point on the line and substituted into $y = mx + c$ or an equivalent expression.
 Both read-offs accurate to half a small square in both the x and y directions.
 Or:
 Intercept read directly from the graph, with read-off at $x = 0$ accurate to half a small square in y direction.

- (f) Value of a = candidate's gradient and value of b = candidate's intercept. [1]
 Units for a and b both correct and consistent with values. [1]

- 2 (a) (ii) All values of D to nearest 0.1 cm and in range 2.0 cm to 4.0 cm. [1]
 Evidence of repeat readings of D . [1]

- (iii) Absolute uncertainty in D in range 0.2 to 0.5 cm and correct method of calculation to obtain percentage uncertainty. If repeated readings have been taken, then the absolute uncertainty can be half the range (but not zero) if the working is clearly shown. [1]

- (iv) Correct calculation of C with consistent unit. [1]

- (b) Justification for significant figures in C linked to significant figures in D only. [1]

- (d) (ii) r_1 in range 5.0 cm to 25.0 cm, with unit, to nearest mm. [1]

- (v) r_2 in range 5.0 cm to 25.0 cm. [1]

- (e) Second value of D . [1]

Second values of r_1 and r_2 . [1]

Second value of $|r_1 - r_2| > \text{first value of } |r_1 - r_2|$. [1]

- (f) (i) Two values of k calculated correctly. [1]

- (ii) Sensible comment relating to the calculated values of k , testing against a criterion specified by the candidate. [1]

Page 4	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	32

(g)	(i) Limitations (4 max.)	(ii) Improvements (4 max.)	Do not credit
A	Two readings are not enough to draw a valid conclusion.	Take more readings <u>and</u> plot a graph/ obtain more k values and <u>compare</u>	“repeat readings”/ “few readings”/ only one reading/ take more readings and (calculate) average k
B	Difficult to measure D (or there is uncertainty in D or C) because loop is not circular/not flat/deforms	Workable method of making a more circular loop, e.g. wrap loop around tube	Use micrometer Use vernier calipers Material weak Material flexible
C	Parallax error with pointer/ pointer moves away from scale/ pointer (or spring) vibrates	Use shadow method	
D	Ruler not vertical	Use set square to ensure ruler vertical/clamp ruler	
E	Difficult to judge reading when loop breaks away/ loop breaks away suddenly	Video with scale/ use maximum marker	Slow motion camera High speed camera Difficult to determine point (or moment) loop breaks away
F	Difficult to lower beaker steadily	Use adjustable-height stand	
G	Reading affected by contact between loop and beaker/ impurities in water	Use larger diameter container/ wider container Use distilled water	Larger beaker

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9702 PHYSICS

9702/33

Paper 3 (Advanced Practical Skills 1),
maximum raw mark 40

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	Cambridge International AS/A Level – May/June 2015	9702	33

- 1 (b) (iv) Value of y in the range 10.0 cm to 11.0 cm with unit. [1]
- (c) (ii) Value of $y >$ value in (b)(iv). [1]
- (d) Six sets of readings of m and y scores 5 marks, five sets scores 4 marks etc. Help from Supervisor –1. [5]
- Range: [1]
Range of m to include $m = 0$ g and $m = 50$ g or 60 g.
- Column headings: [1]
Each column heading must contain a quantity and a unit where appropriate.
The unit must conform to accepted scientific convention e.g. $y(C + m)/\text{cm g}$.
- Consistency: [1]
All values of raw y must be given to the nearest mm.
- Significant figures: [1]
Every value of value of $y(C + m)$ must be given to the same number of s.f. as (or one more than) the least s.f. in the corresponding values of y , C and m as stated in the candidate's table and (a)(ii).
- Calculation: [1]
Values of $y(C + m)$ calculated correctly to the number of s.f. given by the candidate.
- (e) (i) Axes: [1]
Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.
Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions.
Scales must be labelled with the quantity that is being plotted.
Scale markings should be no more than three large squares apart.
- Plotting: [1]
All observations must be plotted.
Diameter of plotted points must be $\leq$ half a small square (no "blobs").
Plotted points must be accurate to within half a small square.
- Quality: [1]
All points in the table (at least 5) must be plotted on the grid for this mark to be awarded.
All points must be within ± 40 g cm of a straight line in the $y(C + m)$ direction.
- (ii) Line of best fit: [1]
Judge by balance of all points on the grid about the candidate's line (at least 5 points). There must be an even distribution of points either side of the line along the full length.
Allow one anomalous point only if clearly indicated by the candidate.
Lines must not be kinked or thicker than half a square.

Page 3	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	33

- (iii) Gradient: [1]
 The hypotenuse of the triangle must be greater than half the length of the drawn line.
 The method of calculation must be correct.
 Both read-offs must be accurate to half a small square in both the x and y directions.

y -intercept: [1]
 Either:
 Correct read-offs from a point on the line and substituted into $y = mx + c$.
 Read-offs must be accurate to half a small square in both x and y directions.
 Or:
 Check read-off of the intercept directly from the graph
 (accurate to half a small square).

- (f) Value of A = candidate's gradient and value of $B = 2 \times$ candidate's intercept / A . [1]
 Do not allow fractions or final answer to 1 s.f.

Unit for A (m, cm or mm) and B (g or kg) correct and consistent with value, with correct power of ten. [1]

- 2 (a) (i) Raw values of d and D to nearest 0.1 mm and with consistent SI unit, in ranges: [1]
 $10.0 \text{ mm} \leq d \leq 25.0 \text{ mm}$
 $20.0 \text{ mm} \leq D \leq 40.0 \text{ mm}$.

- (ii) Value of h with consistent unit in range $40.0 \text{ mm} \leq h \leq 60.0 \text{ mm}$. [1]

- (iii) Percentage uncertainty in d based on absolute uncertainty of 0.1 or 0.2 mm. [1]
 If repeated readings have been taken, then the uncertainty can be half the range (but not zero) if the working is clearly shown.
 Correct method of calculation to obtain percentage uncertainty.

- (b) (iii) Correct calculation of x . Answer must be correct when rounded to 2 s.f. [1]

- (c) Correct justification of s.f. in x linked to s.f. in D , d and h . [1]

- (d) (ii) Value of average $t \geq 0.5 \text{ s}$ with unit. [1]

Evidence of repeated readings (here or in (e)). [1]

- (e) Second value of x . [1]

Second value of t . [1]

Second value of $t <$ first value of t . [1]

- (f) (i) Two values of k calculated correctly. [1]

- (ii) Sensible comment relating to the calculated values of k , testing against a criterion specified by the candidate. [1]

Page 4	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	33

(g)	(i) Limitations (4 max.)	(ii) Improvements (4 max.)	Do not credit
A	Two readings not enough to draw a valid <u>conclusion</u>	Take many readings <u>and</u> plot a graph/ take more readings and compare k values.	“repeat readings”/ “too few readings”
B	Difficulty in release of cylinder from same position every time with reason, e.g. placing fingers in water, level of water surface changing, difficult to judge start point	Better method of holding and releasing cylinder e.g. stop gate/ use mark to ensure the water level is the same for each release	Clamps Force on release
C	Cylinder doesn't always fall vertically (i.e. path at an angle or cylinder tilted)/ hits sides on descent	Method of attaching string symmetrically/ method of symmetrical distribution of mass e.g. use glass beads or sand/ modelling clay <u>distributed evenly</u> / glue marbles in symmetrically	Ignore string effects Sand on its own Narrow cylinder
D	Times short/ large uncertainty in time	Use longer tube/ video with timer (or video and view frame by frame)	Reaction time is short “too fast/quick” High speed camera Light gate(s) Slow motion camera Terminal velocity
E	Difficulty in identifying end point with reason e.g. refraction, glass curvature, tray in the way, bottom of cylinder not flat	Method to identify end point e.g. time to a mark on cylinder/listening to impact	Flat bottomed cylinder Sensors
F	Limited number of marbles to fit in container/ different diameter marbles/ bubbles or air in container/ container deforms when measuring D	Use different shapes e.g. cubes/smaller spheres <u>to occupy more space</u> / use sand/modelling clay <u>to fill more space</u> / measure and account for different diameter of marbles in equation for x	Sand on its own without explanation

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9702 PHYSICS

9702/34

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- 1 (b) (i) Value of r in the range 28.0 cm to 32.0 cm, with unit. [1]
- (c) (ii) Value of T in range 2.0 s to 4.0 s. If out of range, allow Supervisor's value $\pm 20\%$. [1]
- Evidence of repeat measurements for T . [1]
- (d) Six sets of readings of r and T scores 4 marks, five sets scores 3 marks etc. [4]
- Incorrect trend -1 . Help from Supervisor -1 .
- Range: [1]
- $r_{\max} - r_{\min} \geq 30$ cm.
- Column headings: [1]
- Each column heading must contain a quantity and a unit. The presentation of quantity and unit must conform to accepted scientific convention e.g. r^2/m^2 .
- Consistency: [1]
- All values of r must be given to the nearest mm.
- Significant figures: [1]
- The number of significant figures for every value of T^3 must be the same as, or one more than, the number of significant figures in the corresponding time.
- Calculation: [1]
- Values of T^3 calculated correctly to the number of significant figures given by the candidate.
- (e) (i) Axes: [1]
- Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.
- Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions.
- Scales must be labelled with the quantity that is being plotted.
- Scale markings should be no more than three large squares apart.
- Plotting: [1]
- All observations in the table must be plotted on the grid.
- Diameter of plotted points must be $\leq$ half a small square (no "blobs").
- Plotted points must be accurate to within half a small square.
- Quality: [1]
- All points in the table must be plotted (at least 5) for this mark to be awarded.
- All points must be within $\pm 2\text{ s}^3$ of a straight line in the T^3 direction.
- (ii) Line of best fit: [1]
- Judge by balance of all points on the grid about the candidate's line (at least 5 points). There must be an even distribution of points either side of the line along the full length.
- Allow one anomalous point only if clearly indicated (i.e. circled or labelled) by the candidate.
- Lines must not be kinked or thicker than half a square.

Page 3	Mark Scheme	Syllabus	Paper
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- (iii) Gradient: [1]
 The hypotenuse of the triangle must be greater than half the length of the drawn line.
 The method of calculation must be correct.
 Both read-offs must be accurate to half a small square in both the x and y directions.

y -intercept: [1]
 Either:
 Correct read-offs from a point on the line substituted into $y = mx + c$ or an equivalent expression.
 Read-offs must be accurate to half a small square in both x and y directions.
 Or:
 Intercept read directly from the graph, with read-off accurate to half a small square.

- (f) Value of a = candidate's gradient and value of b = candidate's intercept. [1]

Units for a and b are correct (e.g. $\text{s}^3 \text{m}^{-2}$ for a and s^3 for b). [1]

- 2 (a) (ii) Value for t in range 0.10 cm to 0.90 cm and given to nearest 0.01 cm. [1]

Value for D in range 3.0 cm to 6.0 cm. [1]

Value for h less than t . [1]

- (b) Correct calculation of R . [1]

Value of R given to 2 or 3 significant figures. [1]

- (c) (ii) Value for f in range 13.0 cm to 17.0 cm or 28.0 to 32.0 cm. [1]

- (iii) Absolute uncertainty in f in range 0.2 cm to 0.5 cm and correct method of calculation to obtain percentage uncertainty. If repeated readings have been taken, then the absolute uncertainty can be half the range (but not zero) if the working is clearly shown. [1]

- (d) Second values for t , D and h . [1]

Second value for f . [1]

- (e) (i) Two values of k calculated correctly. [1]

Quality: Both k values in range 0.50 to 1.50. [1]

- (ii) Sensible comment relating to the calculated values of k , testing against a criterion specified by the candidate. [1]

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(f)	(i) Limitations (4 max.)	(ii) Improvements (4 max.)	Do not credit
A	Two readings are not enough to draw a valid <u>conclusion</u>	Take more readings <u>and</u> plot a graph/ obtain more k values and <u>compare</u>	“repeat readings”/ “few readings”/ only one reading/ take more readings and (calculate) average k
B	Reason for difficulty in measuring t , h or D e.g. jaws of calipers slip off ends of lens/jaws too short and cannot reach centre of lens	Use a travelling microscope	References to parallax
C	h is small/large uncertainty in h	Use micrometer/travelling microscope	
D	Difficult to obtain sharp image/hard to focus/blurred image	Use a dark(ened) room/ turn off lights/ use point/more compact source of light	
E	Difficult to measure f /take measurement with ruler/measure distance, <u>with reason</u> e.g. difficult to keep lens steady/screen not vertical/lens not vertical/ruler not perpendicular to lens or screen	Mount lens in holder/clamp/ fix lens to bench with e.g. Blu-Tack/ use optical bench	Flexible/bendy screens

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9702 PHYSICS

9702/35

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- 1 (a) (ii) Value of x to the nearest mm with unit, and in range $25.0\text{ cm} < x < 35.0\text{ cm}$. [1]
- (b) (ii) Values of V_1 and V_2 in range $0.100\text{ V} - 2.500\text{ V}$ with unit. Ignore negative sign(s). [1]
- (c) Six sets of readings of x , V_1 and V_2 scores 5 marks, five sets scores 4 marks etc. [5]
 Minor help from supervisor –1, major help –2.
 Inconsistent trend –1 (correct trend is V_2 increases and V_1 decreases as x increases).
- Range: [1]
 Range of values of $x > 60.0\text{ cm}$.
- Column headings: [1]
 Each column heading must contain a quantity and a unit where appropriate.
 The presentation of quantity and unit must conform to accepted scientific convention
 e.g. x/m and V_2/V_1 (no unit).
- Consistency: [1]
 All values of raw V must be given to 0.001 V .
- Significant figures: [1]
 The number of significant figures for V_2/V_1 must be the same as (or one more than) the
 least number of significant figures in the corresponding values of V_2 and V_1 .
- Calculated values: [1]
 V_2/V_1 calculated correctly to the number of s.f. given by the candidate.
- (d) (i) Axes: [1]
 Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.
 Scales must be chosen so that the plotted points occupy at least half the graph
 grid in both x and y directions.
 Scales must be labelled with the quantity that is being plotted.
 Scale markings should be no more than three large squares apart.
- Plotting: [1]
 All observations must be plotted.
 Diameter of plotted points must be $<$ half a small square (no “blobs”).
 Plotted points must be accurate to within half a small square.
- Quality: [1]
 All points in the table must be plotted on the grid for this mark to be awarded.
 All points must be ± 0.025 (to scale) on the V_2/V_1 axis of a straight line.
- (ii) Line of best fit: [1]
 Judge by balance of all points on the grid about the candidate’s line (at least 5
 points). There must be an even distribution of points either side of the line along
 the full length. Allow one anomalous point only if clearly indicated by the
 candidate.

Page 3	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	35

- (iii) Gradient: [1]
 The hypotenuse of the triangle must be greater than half the length of the drawn line.
 The method of calculation must be correct.
 Both read-offs must be accurate to half a small square in both the x and y directions.

y -intercept: [1]
 Either:
 Check correct read-off from a point on the line and substituted into $y = mx + c$.
 Read-offs must be accurate to half a small square in both x and y directions.
 Or:
 Check read-off of the intercept directly from the graph
 (accurate to half a small square).

- (e) Value of $A = 15 \times$ candidate's gradient and value of $B = 10 /$ candidate's y -intercept. [1]
 Do not allow fractions or final answer to 1 s.f.

Units for A ($\Omega \text{ m}^{-1}$ or $\Omega \text{ cm}^{-1}$ or $\Omega \text{ mm}^{-1}$) and $B(\Omega)$ dimensionally correct. [1]

- 2 (c) (i) Value of raw θ to the nearest degree, with unit, in range $\theta < 90^\circ$. [1]

- (ii) Percentage uncertainty in θ based on absolute uncertainty of 2 to 5° , and correct method of calculation. [1]
 If repeated readings have been taken, then the uncertainty can be half the range (but not zero) if the working is clearly shown.

- (iii) Correct calculation of $\cos (\theta/2)$ correct to 2 s.f. [1]

- (d) (ii) Value of T_1 with unit and in range $0.5 \text{ s} < T_1 < 1.5 \text{ s}$. [1]

Evidence of repeats here or in (e)(ii) or (f)(ii). [1]

- (e) (ii) Value of T_2 with unit in range $0.5 \text{ s} < T_2 < 1.5 \text{ s}$. [1]

- (f) (ii) Second value of θ . [1]

Second values of T_1 and T_2 . [1]

Second value of $T_1 >$ first value of T_1
 and
 Second value of $T_2 <$ first value of T_2 . [1]

- (g) (i) Two values of k calculated correctly. [1]

- (ii) Correct justification of s.f. in k linked to s.f. in θ and T_1 and T_2 (or θ and raw times) [but not $\cos (\theta/2)$]. [1]

- (iii) Sensible comment relating to the calculated values of k , testing against a criterion specified by the candidate. [1]

Page 4	Mark Scheme	Syllabus	Paper
	Cambridge International AS/A Level – May/June 2015	9702	35

(h)	(i) Limitations (4 max.)	(ii) Improvements (4 max.)	Do not credit
A	Two readings not enough to draw a valid conclusion	Take many readings for different angles <u>and</u> plot a graph/ take more readings and compare k values	“repeat readings”/ “few readings”
B	Difficult to measure <u>angle</u> with reason e.g. hand shakes/curve at bottom/position of zero uncertain/parallax/rod gets in the way/thick string/holding protractor without a stand	Trace on a card/use graph paper/project onto screen <u>and</u> measure angle/use trigonometry/take photo and measure angle/clamp protractor Use thinner string	
C	Difficult to maintain gap (between strings or stands) or angle <u>with</u> <u>reason</u> e.g. stands move/string slips	Method to prevent movement of stands e.g. G clamp stands/mark positions of stands on bench Make indentations around/in the rod(s) so the strings do not slide/method of fixing string to rod	
D	Movement of rod not confined to the wanted oscillation/rod rotating	Electromagnetic release	Fans/air conditioning
E	Difficult to obtain time with reason e.g. high damping/time too short/no. of oscillations too few/friction between string and rod (loses energy) Large uncertainty in time	Video with timer/frame by frame Longer rod/longer string/heavier rod	
F	Difficult to identify/judge end or highest point of oscillation	Count to middle/fiducial/reference <u>marker at middle</u>	