

**MARK SCHEME for the October/November 2011 question paper
for the guidance of teachers**

9702 PHYSICS

9702/31

Paper 3 (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: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9702	31

- 1 (a) (ii) Value of k in range: $50\text{ cm} \leq k \leq 100\text{ cm}$. [1]
- (b) (iii) Values of d and D both with unit and d in range $4.0 \leq d \leq 6.0\text{ cm}$. [1]
- (c) Six sets of readings of d and D scores 5 marks, five sets scores 4 marks etc. [5]
 Incorrect trend then -1 . Supervisor's help -1 .
 Range of d : $\Delta d \geq 40\text{ cm}$. [1]
 Column headings: [1]
 Each column heading must contain a quantity and a unit where appropriate.
 There must be some distinguishing mark between the quantity and the unit, for example d/m , $d(\text{m})$, $1/D(\text{m}^{-1})$.
 Consistency of presentation of raw readings: [1]
 All values of raw d and D must be given to the nearest mm.
 Significant figures: [1]
 Significant figures for $1/D$ must be the same as, or one more than, the number used in D .
 Calculation: $(D - d)/D$ calculated correctly. [1]
- (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 which is being plotted.
 Scale markings must be no more than three large squares apart.
 Plotting of points: [1]
 All observations in the table must be plotted.
 Check that the points are correctly plotted. Work to an accuracy of half a small square in both x and y directions.
 Do not accept 'blobs' (points with diameter greater than half a small square).
 Quality: [1]
 All points in the table must be plotted (at least 5) for this mark to be scored. Scatter of points must be less than $\pm 0.05\text{ m}^{-1}$ (0.0005 cm^{-1}) of $1/D$ of a straight line.
- (ii) Line of best fit: [1]
 Judge by balance of all the points on the grid (at least 5) about the candidate's line.
 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.

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9702	31

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

Intercept: [1]

Either:

Check correct read-off from a point on the line and substitution into $y = mx + c$. Read-off must be accurate to half a small square in both x and y directions. Allow ecf of gradient value.

Or:

Check the read-off of the intercept directly from the graph.

- (e) $A =$ value of gradient, $B = -$ (value of y -intercept). [1]

$$|A/B| = k \pm 5 \text{ cm with consistent unit.} [1]$$

[Total: 20]

- 2 (a) Measurement of all raw values of t to nearest 0.01 mm or 0.001 mm and t in range $0.10 \leq t \leq 0.50$ mm. [1]
- (b) (i) Value of L in range $26.0 \text{ cm} \leq L \leq 30.0 \text{ cm}$ with consistent unit to nearest mm. [1]
- (ii) Absolute uncertainty in L in range 1–2 mm (but if repeated readings have been taken then the absolute uncertainty could be half the range unless zero).
Correct method shown to find the percentage uncertainty. [1]
- (c) (ii) Correct calculation of V with consistent unit. Allow ecf. [1]
- (e) Value of T in range $0.7 \text{ s} \leq T \leq 1.5 \text{ s}$ with consistent unit. Supervisor help –1. [1]
Evidence of repeats. [1]
- (f) Second value of L in range $5 \text{ cm} \leq L \leq 15 \text{ cm}$. [1]
- (g) Second value of T . [1]
Quality: second value of $T <$ first value of T . [1]
- (h) (i) Two values of k calculated correctly. [1]
- (ii) Justification of s.f. in k linked to raw data in L and T/t . [1]
- (iii) Sensible comment relating to the calculated values of k , testing against a criterion specified by the candidate. [1]

Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9702	31

(i)

	(i) Limitations 4 max.	(ii) Improvements 4 max.	Do not credit
A	Two readings are not enough (to draw a conclusion)	Take more readings and plot a graph/calculate more k values (and compare)	'Few readings'/'take more readings and calculate average k '/'only one reading'
B	Card does not swing freely/ friction between pivot and card	Make hole bigger/bush or bearing idea	
C	Difficult to judge end/start/a complete swing	Use of fiducial marker/pointer	Reaction time error/human reaction/difficult to know when to start/stop timer
D	Irregular/uneven/unusual swings/not in same vertical plane/centre of bottom rule not fixed	Method of keeping shape aligned vertically/turn off fans	
E	Oscillations die out quickly/ heavy damping	Use increased thickness of card	
F	T short/large uncertainty in T	Improved method of timing e.g. <u>video</u> and timer/frame-by-frame. Increase l /length of card	Use of computer/light gates/ camera/high speed camera/ too fast/time too fast/time more swings/time large no. of swings

[Total: 20]

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maximum raw mark 40

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- 1 (a) (i) All raw values of d in the range $0.15 \text{ mm} \leq d \leq 0.40 \text{ mm}$ to 0.01 mm with unit, or supervisor's value $\pm 0.10 \text{ mm}$ [1]
- (b) (iii) l and V with unit. Value of l in the range $40.0 \text{ cm} \leq l \leq 60.0 \text{ cm}$. [1]
- (c) Six sets of readings of l and V scores 5 marks, five sets scores 4 marks etc.
Incorrect trend –1. Major help from supervisor –2. Minor help from supervisor –1. [5]
- Range of l : $\Delta l \geq 50 \text{ cm}$. [1]
- Column headings: [1]
Each column heading must contain a quantity and a unit where appropriate.
There must be some distinguishing mark between the quantity and the unit, e.g. $1/V/V^{-1}$.
Accept $1/V(V^{-1})$ but do not allow $1/V(V)^{-1}$ or $1/l (\text{m})$.
- Consistency of presentation of raw readings: [1]
All values of raw l must be given to 0.001 m.
- Significant figures: [1]
Significant figures for $1/V$ must be to the same as, or one more than, the least number of significant figures used in raw V .
- Calculation: $1/V$ calculated correctly. [1]
- (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 which is being plotted.
Scale markings must be no more than three large squares apart.
- Plotting of points: [1]
All observations in the table must be plotted.
Check that the points are correctly plotted. Work to an accuracy of half a small square in both the x and y directions.
Do not accept 'blobs' (points with diameter greater than half a small square).
- Quality: [1]
All points in the table must be plotted (at least 5) for this mark to be scored. Scatter of points must be less than $\pm 0.2 \text{ m}^{-1}$ (0.002 cm^{-1}) of $1/l$ of a straight line.
- (ii) Line of best fit: [1]
Judge by balance of all the points on the grid (at least 5) about the candidate's line.
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.

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9702	33

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

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

(e) (i) M = value of gradient, N = value of y -intercept. [1]

(ii) Substitution into equation and answer for ρ in range $2 - 20 \times 10^{-7} \Omega \text{ m}$
($0.2 \times 10^{-6} - 2 \times 10^{-6} \Omega \text{ m}$). [1]

[Total: 20]

2 (a) Measurement of all raw w to nearest mm in range $2.0 \leq w \leq 3.5 \text{ cm}$. [1]

(b) (iii) Value of l in range $25 \text{ cm} \leq l \leq 50 \text{ cm}$ with unit. [1]

(c) (ii) Correct calculation of d . Write in correct value if incorrect. Unit not needed. [1]

(iii) Absolute uncertainty in d in the range 3–15 mm (but if repeated readings have been taken then the absolute uncertainty could be half the range, unless zero).
Correct method shown used to find the percentage uncertainty. [1]

(d) Value of T in range $0.3 \text{ s} < T < 1.5 \text{ s}$. [1]

Evidence of repeats. [1]

(e) Second value of l . [1]

Second value of T . [1]

Second value of $T < \text{first value of } T$. [1]

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

(ii) Justification of s.f. in k linked to time AND d or l . [1]

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

Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9702	33

(g)

	(i) Limitations 4 max.	(ii) Improvements 4 max.	Do not credit
A	Two readings are not enough (to draw a conclusion)	Take more readings and plot a graph/ calculate more k values (and compare)	'Few readings'/'take more readings and calculate average k '/'only one reading'
B	Loops not the same size/ ruler(s) not horizontal/	Method to ensure loops same size, e.g. use glue or tape to secure ends together/tie around fixed points/template/mark string	Difficult to tie knots Use of spirit level/use of plumbline Rubber bands or other material Use of Blu-Tack String stretching
C	Difficult to judge end/start/ centre of swing/difficult to judge complete swing	Use of fiducial marker/pointer	Reaction time error Human reaction Difficult to know when to start/stop timer
D	Irregular/uneven/unusual swings/not in same horizontal plane/centre of bottom rule not fixed	Method of ensuring correct release, e.g. (two) stop(s) at either end	Fans/switch off fans Amplitude changes
E	Loops slide	Method, e.g. glue, tape to fix loop to rule/ drill hole to attach string/ make grooves to hold string	'Glue' or 'tape' on its own
F	T or time short/large uncertainty in T	Improved method of timing, e.g. <u>video</u> and timer/frame-by-frame/increase d or l , decrease distance between loops, correct position of motion sensor linked to data logger	Use of computer Light gates Camera High speed camera Too fast Time too fast Time more swings Time large no. of swings.
G	Reason for calculation of d inaccurate, e.g. different w /thickness of rule not taken into account	Measure d directly/measure w for both rules/measure and allow for thickness.	Parallax error Use of set squares Vernier callipers Just 'different w '

[Total: 20]

**MARK SCHEME for the October/November 2011 question paper
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9702 PHYSICS

9702/34

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

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- 1 (a) Measurement for V in range $+0.10\text{ V}$ to $+0.90\text{ V}$, with unit. [1]
- (c) (ii) Six sets of values for R and V scores 6 marks, five sets scores 5 marks etc. [6]
 Incorrect trend –1.
 Major help from supervisor –2, minor help –1.
- Range: [1]
 R values must include $0.33\text{ k}\Omega$ or less and $4.7\text{ k}\Omega$ or more.
- Column headings: [1]
 Each column heading must contain a quantity and a unit where appropriate.
 There must be some distinguishing mark between the quantity and the unit.
- Consistency of presentation of raw readings: [1]
 All raw values of V must be given to the same precision and at least 2 d.p.
- Significant figures: [1]
 $R/(R + 1)$ must be given to the same as or one more than the s.f. for R .
- Calculation: [1]
 $R/(R + 1)$ calculated correctly.
- (d) (i) Axes: [1]
 Sensible scales must be used, no awkward scales (e.g. 3:10).
 Scales must be chosen so that the plotted points must occupy at least half the graph grid in both x and y directions.
 Scales must be labelled with the quantity which is being plotted.
 Scale markings must be no more than 3 large squares apart.
- Plotting of points: [1]
 All observations in the table must be plotted.
 Check that the points are correctly plotted. Work to an accuracy of half a small square.
 Do not accept 'blobs' (points with diameter greater than half a small square).
- Quality: [1]
 All points in the table must be plotted (at least 5) for this mark to be scored.
 Scatter of points must be less than $\pm 0.04\text{ V}$ on the V axis from a straight line.
- (ii) Line of best fit: [1]
 Judge by balance of all the points on the grid (at least 5) about the candidate's line.
 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. There must be 5 points left after the anomalous point is disregarded.

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

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

- (e) a = value of gradient, $b = -(\text{value of intercept})$. Do not allow a fraction. [1]

Value of $|b|$ is in range 1.0 V to 2.0 V, with unit V. [1]

[Total: 20]

- 2 (a) Value of t in range 0.01 to 0.05 mm, with unit. [1]

- (b) (i) Value of w in range 5 to 15 mm. Raw reading(s) must be to nearest mm. [1]

Evidence of repeated readings of w . [1]

- (ii) Percentage uncertainty in w based on absolute uncertainty of 1 mm [1]
 (but if repeated readings have been taken then the absolute uncertainty could be half the range, unless this is zero).
 Correct method used to find the % uncertainty.

- (c) Correct calculation of A using candidate's values from (a) and (b). [1]

- (d) (iii) At least three measurements of F used. [1]

Average calculated correctly, with unit. [1]

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

Second value of F . [1]

F increases as w increases. [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: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9702	34

(g)

	(i) Limitations 4 max.	(ii) Improvements 4 max.	Do not credit
A	Two readings are not enough (to draw a conclusion)	Take more readings and plot a graph/calculate more k values (and compare)	'Few readings'/'take more readings and calculate average k '/'only one reading'
B	Difficult to see maximum/breaking F /break happens suddenly	Video (plus 'slow motion' or 'to view force' or 'to view newton-meter') use maximum-hold newton-meter/ use weights (e.g. sand) to measure F	Just 'use video camera'
C	Difficult to see ends of cuts/difficult to measure w because strip is transparent/ same colour as background	Use contrasting background/mark ends of cuts	'Difficult to measure w '/use coloured polythene
D	w measurement has low precision	Improved method of measuring w e.g. use vernier calliper or use travelling microscope/use larger w	
E	t not constant	Measure t between cuts	Micrometer squashes polythene
F	Large (%) uncertainty/error in t	Improved method of measuring t e.g. measure several layers or use digital micrometer <u>for better precision</u>	
G	Sellotape detaches from bench	Improved method of fixing to bench e.g. use clamp or use wider tape or use glue or use stickier tape	'use stronger tape'
H	t (or w) changes as strip stretches/as F increases	Measure just before or after strip breaks	

Do not allow 'repeated readings'

Do not allow 'use a computer to improve the experiment'

[Total: 20]

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- 1 (a) Raw value(s) of h to the nearest mm in range 5–15 cm. [1]
- (b) (ii) Value of d with unit: $d < h$. [1]
- (d) Six sets of readings of m and d scores 5 marks, five sets scores 4 marks etc. [5]
 Incorrect trend –1. Supervisor's help –1.
- Range of m : $\Delta m \geq 60$ g. [1]
- Column headings: [1]
 Each column heading must contain a quantity and a unit where appropriate.
 There must be some distinguishing mark between the quantity and the unit,
 e.g. $\frac{m}{d}$ / kg m⁻¹ but accept $\frac{m}{d}$ (kg m⁻¹).
- Consistency of presentation of raw readings: [1]
 All values of raw d must be given to the nearest mm.
- Significant figures: [1]
 Significant figures for $\frac{1}{d}$ must be to the same as, or one more than, the number of
 significant figures in d .
- Calculation: m/d calculated correctly. [1]
- (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 which is being plotted.
 Scale markings must be no more than three large squares apart.
- Plotting of points: [1]
 All observations in the table must be plotted.
 Check that the points are correctly plotted. Work to an accuracy of half a small
 square in both x and y directions.
 Do not accept 'blobs' (points with diameter greater than half a small square).
- Quality: [1]
 All points in the table must be plotted (at least 5) for this mark to be scored. Scatter
 of points must be less than ± 0.5 m⁻¹ (0.005 cm⁻¹) of $1/d$ of a straight line.
- (ii) Line of best fit: [1]
 Judge by balance of all the points on the grid (at least 5) about the candidate's line.
 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.

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	GCE AS/A LEVEL – October/November 2011	9702	35

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

Intercept: [1]

Either: Check correct read-off from a point on the line and substitution into $y = mx + c$. Read-off must be accurate to half a small square in both x and y directions. Allow ecf of gradient value.

Or: Check the read-off of the intercept directly from the graph.

- (f) Values of $A = -\text{gradient}$ and $B = \text{intercept}$. [1]

Substitution of $d = h$ shown and $0.08 \text{ kg} < m < 1.0 \text{ kg}$ with consistent unit. [1]

[Total: 20]

- 2 (a) (ii) Value of m in g or kg. $45 \text{ g} \leq m \leq 55 \text{ g}$. [1]

- (iii) Absolute uncertainty in m in range 1–5 g with unit. [1]
Correct method shown to find the percentage uncertainty.

- (b) (iii) Value of V to at least 1 d.p. with unit. Supervisor help –1. [1]

- (c) Raw value(s) of θ_1 to nearest $^\circ\text{C}$. [1]

- (d) (ii) Value of $\theta_2 > \theta_1$ with unit. [1]

- (iii) Calculation of $(\theta_2 - \theta_1)$. [1]

- (e) Second value of $V > \text{first value of } V$. [1]

- (f) Second values of θ_2 and θ_1 . [1]

Second value of $(\theta_2 - \theta_1) > \text{first value of } (\theta_2 - \theta_1)$. [1]

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

- (ii) Justification of s.f. in k linked to raw data in V and $(\theta_2 - \theta_1)$. [1]

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

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(h)

	(i) Limitations 4 max.	(ii) Improvements 4 max.	Do not credit
A	Two readings are not enough (to draw a conclusion)	Take more readings and plot a graph/calculate more k values (and compare)	'Few readings'/'take more readings and calculate average k '/'only one reading'
B	Heat loss (to surroundings or beaker)	Method to reduce heat loss, e.g. lagging, lid	Switch off fans to reduce convection
C	Small value of $(\theta_2 - \theta_1)/\%$ uncertainty in $(\theta_2 - \theta_1)$ is large	Method to increase $(\theta_2 - \theta_1)$ e.g. higher voltage, lower resistance, increased time, less water	
D	Low precision of thermometer	Either: thermometer with <u>specified</u> better precision, e.g. 0.1°C , 0.5°C Or: named device such as thermocouple or resistance thermometer.	Not accuracy
E	Resistor/bulb of thermometer is not completely immersed	Use narrower beaker	
F	Water is left behind in measuring cylinder	Method to measure mass of water, e.g. subtract mass of empty beaker from mass of beaker with water	Just "weigh water"
G	Resistor continues to give out heat when switched off/ temperature continues to rise after switching off	Wait until temperature reaches a maximum before reading	

Do not credit: precision of measuring cylinder; different starting temperatures of water; uneven temperature distribution in beaker; parallax errors in reading volume or temperature; reaction time error in timing.

[Total: 20]

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
GCE Advanced Subsidiary Level and GCE Advanced Level

**MARK SCHEME for the October/November 2011 question paper
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9702 PHYSICS

9702/36

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

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- 1 (b) Measurement for H in range 0.200 m to 0.900 m. [1]
- (c) (ii) First measurement of m , to nearest 0.001 kg and in the range 0.045 to 0.055 kg. [1]
- (d) Six sets of values for h and m scores 5 marks, five sets scores 4 marks etc. [5]
 Incorrect trend then –1. Help from supervisor –1.
- Range: [1]
 m values must include 0.070 kg or less, and 0.220 kg or more.
- Column headings: [1]
 Each column heading must contain a quantity and a unit where appropriate.
 There must be some distinguishing mark between the quantity and the unit.
 e.g. y^2/m^{-2} , $1/m^2(1/kg^2)$ but not $\frac{1}{m^2/kg^2}$.
- Consistency of presentation of raw readings: [1]
 All values of h must be given to the nearest mm.
- Significant figures: [1]
 Every value of $1/y^2$ must be given to the same s.f. as (or one more than) the s.f. in y .
- Calculation: [1]
 $1/y^2$ calculated correctly.
- (e) (i) Axes: [1]
 Sensible scales must be used, no awkward scales (e.g. 3:10).
 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 which is being plotted.
- Plotting: [1]
 All observations must be plotted.
 Check that the points are correctly plotted. Work to an accuracy of half a small square.
 Do not accept 'blobs' (points with diameter greater than half a small square).
- Quality: [1]
 Scatter of points must be less than $\pm 50 m^{-2}$ ($\pm 0.005 cm^{-2}$) on the $1/y^2$ axis about a straight line. All points must be plotted (at least 5) for this mark to be scored.
- (ii) Line of best fit: [1]
 Judge by balance of all the points (at least 5) about the candidate's line. There must be an even distribution of points either side of the line along the full length.
 Allow one anomalous point if clearly indicated by the candidate.
 Line must not be kinked or thicker than half a square.

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9702	36

- (iii) Gradient: [1]
 The hypotenuse must be at least half the length of the drawn line.
 Both read-offs must be accurate to half a small square or better in both x and y directions.
 The method of calculation must be correct. Do not allow $\Delta x/\Delta y$.

- Intercept: [1]
 Either: Check correct read-off from a point on the line, and substitution into $y = mx + c$. Read-off must be accurate to half a small square or better in both x and y directions. Allow ecf of gradient value.
 Or: Check the read-off of the intercept directly from the graph.

- (f) p = value of gradient and $q = -$ (value of intercept). [1]
 Both values must be from (e)(iii). Do not allow fractions.

Correct consistent units for p (e.g. $\text{kg}^2 \text{m}^{-2}$) and q (e.g. m^{-2}). [1]

[Total: 20]

- 2 (b) $0.250 \text{ m} \leq a \leq 0.350 \text{ m}$ and $0.450 \text{ m} \leq b \leq 0.550 \text{ m}$, both with a correct and consistent unit. [1]

Values of a and b given to nearest mm e.g. 0.350 m or 35.0 cm . [1]

- (c) (ii) Value of R in range 0.05 m to 0.50 m (5 cm to 50 cm). [1]

Evidence of repeats (credit evidence here or in (f)). [1]

- (d) Percentage uncertainty in R based on absolute uncertainty in range 0.002 m to 0.01 m (2 mm to 10 mm). [1]
 (If repeated readings have been done then the absolute uncertainty could be half the range, unless this is zero.)
 Correct method to get % uncertainty.

- (e) Correct calculation of v with consistent unit. [1]

- (f) (ii) Second values of a and b . [1]

Second value of R . [1]

Second R less than first R . [1]

Correct calculation of second v . [1]

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

- (ii) Valid conclusion based on the variation in k being within (or outside) a stated criterion. [1]

Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2011	9702	36

(h)

	(i) Limitations 4 max.	(ii) Improvements 4 max.	Do not credit
A	Two readings are not enough (to draw a conclusion)	Take more readings <u>and plot a graph</u> /calculate more k values (and compare).	Few readings/only one reading/take more readings and calculate average k /'repeat readings'
B	Difficult to locate <u>start position</u> / <u>measure R</u> owing to parallax	Method to locate start point e.g. plumb line/clamped vertical rule using set square to bench	'Parallax error'/parallax error linked to a or b
C	Difficult to <u>locate end point</u> / <u>measure R</u> owing to ball bouncing/skipping/sinking/rule displaced from ball	Method to locate end point of R e.g. vertical clamped pointer/tray without lip (so rule can be placed on sand)/sand on bench/carbon paper /painted ball/video with playback <u>plus scale in shot</u> /detailed hot spot	Vague video methods/ball moves/smooth sand/change depth of sand
D	Difficult to release ball from rest/without exerting a force	Method of improving release e.g. use an electromagnet	Use a release mechanism
E	(Vertical) distance fallen is less than a	Method of measuring a to surface of sand/correcting the value of a by measuring depth of sand	
F	Difficult to make tube horizontal (as not flexible enough)/judge horizontal/ clamp blocks horizontally	Method to ensure tube is horizontal e.g. use reference line (window sill)/spirit level /measure several heights from bench.	
G	Ball sticks in tube/slows down due to e.g. sand in tube/bend in tube/kink in tube/too much friction	Method to overcome sticking e.g. use new ball each time /clean ball with cloth before putting back in tube/use wider tube/smaller ball/open track	Lubricate/clean tube

Do not allow 'rule is not perpendicular to bench'.

Do not allow unspecified computer methods.

[Total: 20]