

MARK SCHEME for the May/June 2010 question paper
for the guidance of teachers

9702 PHYSICS

9702/31

Paper 31 (Advanced Practical Skills), 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 – May/June 2010	9702	31

1 (a) Ring e.m.f. value

- (c) Six sets of values for V and I scores 5 marks, five sets scores 4 marks, etc. [5]
 Indicate the number of sets of readings.
 Incorrect trend –1 (wrong trend N increases, I increases).

Apparatus correctly set up without help from supervisor. [2]
 Major help –2, minor help –1

Range of N in table to include 1 or 2 and 11 or 12. [1]

Column headings (N (no unit), V/V , I/A , R/Ω , $(1/R)/\Omega^{-1}$) [1]
 Each column heading must contain a quantity and a unit where appropriate.
 Ignore units in the body of the table.
 There must be some distinguishing mark between the quantity and the unit (solidus is expected but accept for example, $V(V)$).

Consistency of presentation of raw readings of I and V . [1]
 All values of I must be given to the same number of decimal places.
 All values of V must be given to the same number of decimal places.

Significant figures. [1]
 S.f. for $1/R$ must be the same as, or one more than, the least number of s.f. used in I or V .
 Check each row.

Values of $1/R$ correct. Underline and check the specified value of $1/R$. [1]
 If incorrect, write in the correct value.

(d) Graph

- (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. Indicate false origin with FO.
 Scales must be labelled with the quantity that is being plotted. Ignore units.
 Allow inverted axes but do not allow the wrong graph.
 Scale markings should be no more than three large squares apart.

All observations must be plotted. [1]
 Write a ringed total of plotted points.
 Do not accept blobs (points > 0.5 small square).
 Ring and check a suspect plot. Tick if correct. Re-plot if incorrect.
 Work to an accuracy of half a small square.

- (ii) Line of best fit [1]
 Judge by balance of at least 5 trend points about the candidate's line.
 There must be an even distribution of points either side of the line along the whole length. Indicate best line if candidate's line is not the best line.
 Lines must not be kinked.

Quality [1]
 Judge by scatter of all points about a straight line.
 All plots from table (minimum 5) must be within 1 mA of a straight line.
 Do not award if wrong graph or wrong trend.

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	31

(iii) Gradient [1]

The hypotenuse of the triangle must be at least half the length of the drawn line.

Both read-offs must be accurate to half a small square.

If incorrect, write in correct value.

Check for $\Delta y/\Delta x$ (i.e. do not allow $\Delta x/\Delta y$).

y-intercept from graph or substitute correct read-offs into $y = mx + c$ [1]

(Expect close to 0). Label FO.

(e) M = gradient value. L = y-intercept value. No substitution method. [1]

If inverted axes not corrected for -1

Value of M = value from part (a) $\pm 0.5V$. [1]

Value of L = 0 ± 1 mA.

Appropriate units

[Total: 20]

2 (b) Total time over which swings are measured > 10 s. [1]

Correct calculation of $T = T_n/n$. [1]

(c) (i) Value of $l = 5$ cm ± 1 cm [1]

Evidence of repeats in length value (here or in d(iii)). [1]

(ii) Measure in two different places/check zero error. [1]

(iii) Percentage uncertainty in length. Consistent units. $\Delta l = 0.1$ mm [1]

If repeated readings have been taken, then the uncertainty can be half the range.

Correct ratio idea required ($0.1/\text{length} \times 100\%$).

(d) (ii) Measurement of time for longer tube. [1]

$t_{\text{longer tube}} < t_{\text{shorter tube}}$ [1]

(iii) Measurement of length for longer tube to the nearest 1 mm. [1]

Consistent unit

(iv) Add two lengths together correctly. Allow rounding. [1]

(e) Correct calculation of two values of $k = T^2/l$. [1]

Valid conclusion based on the calculated values of k . [1]

Candidate must test against a specified criterion.

Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	31

	Limitations (4)	Improvements (4)	Ignore
A	A_p Two readings not enough (to support conclusion)/too few readings.	A_s Take many readings <u>and</u> plot a graph/compare values of k . Do not allow average k .	Repeat readings
B	B_p (l inaccurate because) gap between long and short tube/ ends of tubes uneven. Tubes not straight/kinked/disjointed.	B_s Get one long tube without a break/stick two tubes together/use longer tube on its own. Method of smoothing ends.	Parallax error
C	C_p Tube(s) not vertical when stationary/ not aligned with string.	C_s Smaller diameter tube/thicker walled tube/suitable method of alignment.	Thicker string
D	D_p Not swinging in one plane only/idea of non-uniform oscillation.	D_s Method of reducing draught e.g. close windows, turn off fans, screen experiment.	
E	E_p <u>Time</u> difficult to measure because difficult to know when oscillation returns to original position/maximum height.	E_s A marker to time as passes centre/reaches maximum displacement. Light gate at centre with timer/motion sensor at end with data logger/video with timer (playback) in slow motion.	Difficult to release from same point each time/ human error/reaction time/unqualified use of light gates/sensors

X_p/X_s Other valid suggestions (e.g. knot slipping) with valid method.

[Total: 20]

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	GCE AS/A LEVEL – May/June 2010	9702	32

- 1 (b) Six sets of values for N and I scores 5 marks, five sets scores 4 marks, etc. [5]
 Incorrect trend –1.
- Apparatus set up correctly without help from supervisor. Minor help –1, [2]
 major help –2
- Range – [1]
 To include $N = 1$ or 2 and $N = 11$ or 12.
- Column headings – [1]
 Each column heading must contain a quantity and a unit where appropriate.
 Ignore units in the body of the table.
 There must be some distinguishing mark between the quantity and the unit
 (solidus is expected, but accept, for example, I (A))
- Consistency of presentation of raw readings of I – [1]
 All raw values of I must be given to the same number of decimal places.
- Significant figures – [1]
 S.f. for $1/I$ must be the same as, or one more than, the s.f. for I .
 Check each row.
- Values of $1/I$ correct – [1]
 Underline and check the specified value of $1/I$. If incorrect, write in the correct value.
- (c) (i) Graph [1]
 Axes –
 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. Indicate false origin with FO.
 Scales must be labelled with the quantity that is being plotted. Ignore units.
 Allow inverted axes but do not allow the wrong graph.
 Scale markings should be no more than three large squares apart.
- Plots – [1]
 All observations must be plotted. Write a ringed total of plotted points.
 Do not accept blobs (points > half a small square).
 Ring and check a suspect plot. Tick if correct. Re-plot if incorrect.
 Work to an accuracy of half a small square.
- (ii) Line of best fit – [1]
 Judge by the balance of at least 5 trend plots about the candidate's line.
 There must be an even distribution of points either side of the line along the whole length. Indicate best line if candidate's line is not the best line.
 Line must not be kinked or thicker than 1 mm.
- Quality – [1]
 Judge by scatter of all points about a straight line.
 All plots in the table must be within 10Ω of a straight line.
 Do not award if wrong graph or wrong trend.

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	32

- (iii) Gradient – [1]
 The hypotenuse of the triangle must be at least half the length of the drawn line.
 Both read-offs must be accurate to half a small square. If incorrect, write in the correct value.
 Check for $\Delta y/\Delta x$ (i.e. do not allow $\Delta x/\Delta y$).

y-intercept – [1]
 Either from graph or by substitution of correct read-offs into $y = mx + c$.
 Check for and label false origin.

- (d) G = gradient value and H = intercept value. [1]
 Do not credit if a substitution method is used.

Range of values ($-70\Omega \leq H \leq -30\Omega$ and $3.5\text{ V} \leq G \leq 5.5\text{ V}$) with appropriate units. [1]
 Do not credit if a substitution method is used.

[Total: 20]

- 2 (b) (i) Value of maximum force to 1 d.p. in raw data and greater than 0 N. [1]
 Evidence of repeated measurements of F in (b)(i) or (d). [1]

(ii) Reaches maximum force suddenly (short time); no notice given when releases. [1]

(iii) Percentage uncertainty in maximum force. [1]
 $0.1\text{ N} \leq \Delta F \leq 0.4\text{ N}$. If repeated readings have been done then the uncertainty could be half the range. Correct ratio idea required (e.g. $0.2 / F \times 100\%$).

(c) (i) Measurement of raw t to the nearest 0.01 mm. [1]

(ii) Take repeats in different places / (account for) zero errors. [1]

(iii) Maximum force with three slides. Unit required. [1]

(d) Measurement of thickness of one slide. [1]

Measurement of maximum force with one slide. [1]

Quality: $F_{(b)(i)} > F_{(d)} > F_{(c)(iii)}$ [1]

(e) Calculation of two values of k . [1]

Valid conclusion based on the calculated values of k . [1]

Candidates must test against a specified criterion.

Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	32

(f)(i),(ii) Identify limitations and improvements

	Limitations (4)	Improvements (4)	Do not credit
A	Two readings are not enough (to support conclusion)	Take more (sets of) readings <u>and</u> <u>plot a graph</u>	Repeat readings.
B	Maximum force reached without warning (if not already credited in (b)(ii))	B_s Practical method of recording maximum value e.g. video <u>with</u> playback in slow motion / max-min newton metre / force sensor <u>with</u> data logger / masses with pulley.	Parallax error. Solution for parallax error. 'Use of computer' to measure maximum force.
C	t changes due to compression force of magnets / slide thickness non uniform (if not already credited) / thread thickness adds to separation.	Method of attaching newton meter without thread / measure and add thread thickness.	
D	Zero error on newton meter <u>when used horizontally</u> .	Adjust zero / practical vertical arrangement.	Condition of newton meter.
E	Glass may affect magnetic force / effect of surrounding magnetic materials (e.g. G clamp).	Use a variety of materials to separate magnets and test if material affects results / use a non magnetic clamp / glue first magnet to bench.	Reference to Earth's field.
F	Friction with bench.	Method of reducing friction.	
G	Difficulties with alignment of force with magnets.	Method of raising magnets / longer loop.	
X	Difficult to measure force due to weak magnets / small force (if validated by SR)	More sensitive newton meter.	

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	GCE AS/A LEVEL – May/June 2010	9702	33

- 1 (c) Six sets of readings of I and V scores 5 marks, five sets scores 4 marks, etc. [5]
 Indicate the number of sets of readings.
 Incorrect trend –1 (wrong trend is I increases, V^{10} decreases).
- Apparatus correctly setup without help from supervisor. [2]
- Range of I : $I_{\min} \leq 10 \text{ mA}$ and $I_{\max} \geq 35 \text{ mA}$. Ignore POT errors. [1]
- Column headings (e.g. V/V , I/A , V^{10}/V^{10}). [1]
 Must have V and I columns.
 Each column heading must contain a quantity and a unit where appropriate.
 Ignore units in the body of the table.
 There must be some distinguishing mark between the quantity and the unit.
 (solidus is expected but accept, for example, $V(V)$)
- Consistency of presentation of raw readings. [1]
 All values of V must be given to the same number of decimal places (must have dp).
 All values of I must be given to the same number of decimal places.
- Significant figures.
 Sf for V^{10} must be the same as or one more than the sf used in V . Check each row. [1]
- Values of V^{10} correct. Underline and check the specified value of V^{10} . [1]
 If incorrect, write in the correct value.

(d) Graph

(i) Axes

- Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. [1]
 Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Indicate false origin with FO.
 Scales must be labelled with the quantity that is being plotted. Ignore units.
 Allow inverted axes but do not allow the wrong graph.
 Scale markings should be no more than three large squares apart.

Plots

- All observations must be plotted. [1]
 Write a ringed total of plotted points.
 Do not accept blobs (points > 0.5 small square).
 Ring and check a suspect plot. Tick if correct. Re-plot if incorrect.
 Work to an accuracy of half a small square.

(ii) Line of best fit

- Judge by balance of at least 5 trend points about the candidate's line. [1]
 There must be an even distribution of points either side of the line along the whole length. Indicate best line if candidate's line is not the best line.
 Lines must not be kinked.

Quality

- Judge by scatter of all points about a straight line.
 All points in table (minimum 5) must be within 2 mA of a straight line. [1]
 Do not award if wrong graph or wrong trend.

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	33

- (iii) Gradient
 The hypotenuse of the triangle must be at least half the length of the drawn line. [1]
 Both read-offs must be accurate to half a small square.
 If incorrect, write in correct value.
 Check for $\Delta y/\Delta x$ (i.e. do not allow $\Delta x/\Delta y$).

y-intercept from graph or substitute correct read-offs into $y = mx + c$ [1]
 Label FO.

- (e) $a =$ gradient value and $b =$ y-intercept value. [1]
 If inverted axes not corrected for -1
 Range of values ($0.1AV^{-10} \leq a \leq 0.9AV^{-10}$, $b = 0 \pm 0.01A$) and appropriate units [1]

[Total: 20]

- 2 (a) Raw value(s) of x : $25.0 \text{ cm} \leq x \leq 35.0 \text{ cm}$ with unit to nearest mm. [1]
- (b) (i) Evidence of repeated measurements of d in (b)(i) or (e) [1]
 Value of $d = 3.0 \text{ mm} \pm 1.0 \text{ mm}$ or $SV \pm 1.0 \text{ mm}$ [1]
 Raw values of d to at least 0.1 mm
- (ii) Value of t in range 1 s to 10 s unless SV indicates otherwise. Allow $SV \pm 5 \text{ s}$ [1]
- (c) Absolute uncertainty in t_1 in the range 0.1 to 0.6 s [1]
 If repeated readings have been taken, then the uncertainty could be half the range.
 Correct calculation to get % uncertainty.
- (d) v calculated correctly with consistent units. [1]
- (e) Second value for d . [1]
 Second value for t . [1]
 Quality: t_2 less than t_1 . (d increases, t decreases) [1]
- (f) (i) Calculation of two values of k . [1]
 (ii) Valid conclusion based on the calculated values. [1]
 Candidate must test against a specified criterion.
- (iii) Relate raw values of x , t and d . Any decimal place arguments score zero. [1]

Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	33

	Limitations (4)	Improvements (4)	Ignore
A	A_p Two readings not enough (to support conclusion)/too few readings.	A_s Take more (sets of) readings <u>and</u> plot a graph/compare values of k.	Repeat readings.
B	B_p Time too short/reaction time large compared to measured time/parallax error in judging start/stop.	B_s Increase x/lengthen tube/smaller balls/video with timer (playback) in slow motion.	Light gates, motion sensors, data loggers, computers, helpers, solution for parallax error. Set squares, rulers, etc.
C	C_p Difficult to see glass balls.	C_s Use coloured balls/shine light through.	Use ball bearings (type of ball and oil stays fixed).
D	D_p Terminal velocity not reached (by the first marker).	D_s A valid method to check reached TV, e.g. <u>time constant</u> over three markers/video with timer (playback) in slow motion, multi-flash photography/stroboscope.	References to starting point. Do not accept 'move x down' on its own. Change viscosity of oil (oil and glass must remain fixed).
E	E_p Balls not all the same diameter/size/shape/mass	E_s Use micrometer screwgauge/top pan balance	
X	X_p Balls had a hole in/air bubbles on ball or oil.	X_s Clean balls/immerse in oil	

[Total: 20]

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	GCE AS/A LEVEL – May/June 2010	9702	34

- 1 (a) Apparatus set up without help from Supervisor. [1]
Value of L to nearest mm. [1]
- (d) Table –
Six sets of readings of d and h scores 5 marks, five sets scores 4 marks, etc. [5]
Incorrect trend –1.
- Range –
Range of values of $d \geq 15$ cm. [1]
- Column headings –
Each column heading must contain a quantity and a unit. Ignore units in the body of the table.
There must be some distinguishing mark between the quantity and the unit e.g. $1/d / \text{m}^{-1}$ or $1/d (\text{m}^{-1})$. [1]
- Consistency –
All raw values of h must be given to the nearest mm. [1]
- Significant figures –
S.f. for $1/d$ must be the same as, or one more than, the s.f. given for raw d . Check each row. [1]
- Calculated values –
Check the specified value of $1/d$. If wrong, write in the correct value. [1]
- (e) (i) **Graph**
Axes –
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. Indicate a false origin with FO.
Scales must be labelled with the quantity that is being plotted. Ignore units.
Allow inverted axes but do not allow the wrong graph.
Scale markings should not be more than three large squares apart. [1]
- Plotting of points –
All observations must be plotted.
Do not accept 'blobs' (points $>$ half a small square).
Ring and check a suspect point. Tick if correct. Re-plot if incorrect.
Work to an accuracy of half a small square. [1]
- (ii) **Line of best fit –**
Judge by the balance of at least 5 trend points about the candidate's line. There must be an even distribution of points either side of the line along the whole length.
Indicate best line if candidate's line is not the best line. [1]
Line must not be kinked or thicker than 1 mm.
- Quality –
Judge by scatter of all points about a best line. All plots from table (minimum 5) must be within 0.1 m^{-1} of a straight line (in $1/d$ direction).
Do not credit if it is the wrong graph or if the trend is wrong. [1]

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	34

- (iii) Gradient –
 The hypotenuse of the triangle must be at least half the length of the drawn line.
 Read-offs must be accurate to half a small square – if wrong write in the correct value(s).
 Check for $\Delta y/\Delta x$ (i.e. do not allow $\Delta x/\Delta y$). [1]

y-intercept –
 Value must be read from graph to nearest half small square (after checking for false origin) or calculated using ratios or $y = mx + c$. [1]

- (f) Correct calculation of z (gradient value must be used). [1]
 Ignore sign. [1]
 Value of z given with unit of length (gradient value must be used). [1]

[Total: 20]

- 2 (a) Measurement of I in range 1.5 A–2.5 A and to 0.1A or better. [1]
- (c) Measurement of x to the nearest mm. [1]
- (d) Measurement of θ (less than 45°). Raw values to no more than nearest degree or half degree. [1]
- (e) Percentage uncertainty in θ : Correct method, using $\Delta\theta = \text{half the range}$, or $\Delta\theta = 2^\circ$ to 10° . [1]
- (f) (i) Evidence of repeated measurements either here or in (d). [1]
 (ii) Correct average value of θ . [1]
- (g) Second measurement of x . [1]
 Second measurement of I . [1]
 Quality: I decreases as x decreases. [1]
- (h) (i) Correct calculation of two values of k . [1]
 (ii) Valid conclusion based on the calculated values of k . Candidate must test against a specified criterion. [1]
 (iii) Statement that the s.f. for k depend on the s.f. for I and x . Ignore any reference to d.p. [1]

Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	34

(i) Identifying limitations and suggesting improvements

	Limitations (4)	Improvements (4)	Ignore
A	Two readings (of x and I) are not enough (to draw a valid conclusion).	Take more readings <u>and plot a graph</u> .	Repeat readings.
B	<u>Difficult</u> to measure x / <u>difficult</u> to keep x constant / <u>difficult</u> to keep distance between wire and magnet constant / <u>difficult</u> to keep distance between wire and stick constant.	Use a clamped ruler / method of fixing the string	Parallax error in measuring x .
C	Magnet does not come to rest.	Practical method of damping / shield from draughts / turn off fans.	Magnet swings too fast.
D	Measured angles are very small	Use larger currents / use bigger protractor	Use stronger / larger magnet.
E	Parallax error <u>in measuring θ / reading protractor / reading deflection</u> .	Method of bringing protractor closer to wire / shine light from above	Increase x / use mirror.
F	Difficult to alter rheostat while holding string.	Method of fixing the string (unless already credited in B) / method of fixing rheostat to bench / use assistant.	
G	(θ affected by) magnetic materials nearby / stray magnetic fields.	Use wooden / non-magnetic stands.	Move object further away.
H	Fluctuating current.	Method of improving contact with wire (e.g. cleaning contacts, soldered connections).	

Do NOT credit: Use sensors / use lightgates / use video.

[Total: 20]

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- 1 (c) Six sets of readings of I and V scores 5 marks, five sets scores 4 marks, etc. [5]
 Indicate the number of sets of readings.
 Incorrect trend then -1 (wrong trend P increases, R^4 decreases).
- Apparatus correctly set up without help from supervisor. [2]
 Major help -2 , minor help -1
- Range of V : $V_{\min} \leq 2\text{ V}$ and $V_{\max} \geq 10\text{ V}$. [1]
- Column headings (V/V , I/A , P/W , R/Ω , R^4/Ω^4) [1]
 Must have V and I columns.
 Each column heading must contain a quantity and a unit where appropriate.
 Ignore units in the body of the table.
 There must be some distinguishing mark between the quantity and the unit (solidus is expected but accept, for example, $V(V)$).
- Consistency of presentation of raw readings. [1]
 All raw values of V must be given to the same number of decimal places and this must be 0.1 V .
 All raw values of I must be given to the same number of decimal places
- Significant figures. [1]
 S.F. for P must be the same as, or one more than, the least number of S.F. used in V or I . Check each row.
- Values of R^4 correct. Underline and check the specified value of R^4 . [1]
 If incorrect, write in the correct value.
- (d) (i) Graph [1]
 Axes: 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. Indicate false origin with FO.
 Scales must be labelled with the quantity which is being plotted. Ignore units.
 Allow inverted axes but do not allow wrong graph.
 Scale markings should be no more than three large squares apart.
- Plots
 All observations must be plotted.
 Write a ringed total of plotted points. [1]
 Do not accept blobs (points > 0.5 small square).
 Ring and check a suspect plot. Tick if correct. Re-plot if incorrect.
 Work to an accuracy of half a small square.
- (ii) Line of best fit [1]
 Judge by balance of at least 5 trend points about the candidate's line.
 There must be an even distribution of points either side of the line along the whole length. Indicate best line if candidate's line is not the best line.
 Lines must not be kinked.
- Quality [1]
 Judge by scatter of all points about a straight line.
 All points in the table (minimum 5) must be within 50 mW of a straight line.
 Do not award if wrong graph or wrong trend.

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	35

- (iii) Gradient [1]
 The hypotenuse of the triangle must be at least half the length of the drawn line.
 Both read-offs must be accurate to half a small square.
 If incorrect, write in correct value.
 Check for $\Delta y / \Delta x$ (i.e. do not allow $\Delta x / \Delta y$).

y-intercept from graph or substitute correct read-offs into $y = mx + c$ [1]
 Label FO.

- (e) a = gradient value and b = y-intercept value. [1]
 Units for a and b are correct (expect $W\Omega^{-4}$ for a and W for b). [1]
 Range: $a = 3 \times 10^{-9} \pm 1 \times 10^{-9}$ or $SV \pm 33\%$

[Total: 20]

- 2 (a) (ii) Value of d , with consistent unit. Range of d : 5 ± 1 cm [1]
 d to nearest mm. [1]
- (c) (ii) Evidence of repeated measurements of t either in (c)(ii) or (e)(ii). [1]
 Value of t in range 5 to 30 s. [1]
- (d) Absolute uncertainty in t in the range 0.5 to 1.0 s. [1]
 If repeated readings have been taken, then the uncertainty can be half the range.
 Correct calculation to get % uncertainty. [1]
- (e) (ii) Second value for d . [1]
 Second value for t . [1]
 Quality: t_2 less than t_1 . [1]
- (f) (i) Correct calculation of two values of k or equivalent. [1]
- (ii) Valid conclusion based on the calculated values of k . [1]
 Candidate must test against a specified criterion.
- (iii) Justification with reference to the significant figures in t and d . [1]

Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE AS/A LEVEL – May/June 2010	9702	35

(g)

	Limitations (4)	Improvements (4)	Ignore
A	A_p Two readings not enough (to support conclusion) / too few readings.	A_s Take more (sets of) readings <u>and</u> plot a graph / compare values of k .	Repeat readings
B	B_p Marker never exactly on 2 cm or 0.5 cm: either above or below / increments in changes in amplitude too large / difficult to judge 2 cm and 0.5 cm.	B_s Video with timer (playback) in slow motion / position sensor above with data logger / measure the amplitudes over time.	Use computer to improve the experiment. Multi-flash photography? Light gates.
C	C_p Straw not vertical (straight) / straw bumping into sides/ non-vertical oscillation.	C_s Wider container / glue straw / method of alignment.	No ref to changing oil
D	D_p Difficult to measure ' d ' because of lining up meniscus / refraction of curved container.	D_s Mark straw/ mark container / use travelling microscope / vernier calliper?	
E	E_p Difficult to measure time because moves past the marker quickly / small distances involved.	E_s Video with timer (playback) in slow motion / position sensor above with data logger. Credit once only.	

[Total: 20]