
PHYSICS

9702/31

Paper 3 Advanced Practical Skills 1

October/November 2019

MARK SCHEME

Maximum Mark: 40

Published

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GENERIC MARKING PRINCIPLE 1:

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- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

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- marks are awarded when candidates clearly demonstrate what they know and can do
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- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

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GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

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Question	Answer	Marks
1(a)	Value of $V < 2.0 \text{ V}$ with unit.	1
1(b)	Value of d with unit and in the range 20.0–90.0 cm.	1
1(c)	Six sets of readings of R and d (different values) showing the correct trend and without assistance from the Supervisor scores 5 marks, five sets scores 4 marks etc.	5
	Range: Values of R must include 12Ω and 39Ω .	1
	Column headings: 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. d/m and R/Ω and $R/d/\Omega \text{ m}^{-1}$.	1
	Consistency: All values of d must be given to the nearest mm.	1
	Significant figures: All values of R/d must be given to either 2 or 3 s.f.	1
	Calculation: Values of R/d are correct.	1
1(d)(i)	Axes: Sensible scales are 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 that is being plotted. Scale markings should be no more than three large squares apart.	1
	Plotting of points: All observations must be plotted on the grid. Diameter of plotted point must be $\leq$ half a small square. Points must be plotted to an accuracy of half a small square.	1
	Quality: All points in the table (at least 5) must be plotted on the grid for this mark to be awarded. Trend of points on graph must be positive. All points must be within 2.5Ω on the R -axis of a straight line.	1

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Question	Answer	Marks
1(d)(ii)	Line of best fit: Judge by the balance of all 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 its full length. One anomalous point is allowed only if clearly indicated (i.e. circled or labelled) by the candidate. There must be at least 5 points left after the anomalous point is disregarded. Line must not be kinked or thicker than half a square.	1
1(d)(iii)	Gradient: The hypotenuse of the triangle used should be greater than half the length of the drawn line. Both read-offs must be accurate to half a small square in both the x and y directions. The sign of the gradient on the answer line must match the graph. Method of calculation must be correct, e.g. not $\Delta x / \Delta y$.	1
	y-intercept: Correct read-off from a point on the line substituted into $y = mx + c$ or an equivalent expression. Read-off must be accurate to half a small square in both x and y directions. or Intercept read directly from the graph, with read-off at $R = 0$, accurate to half a small square in the R direction.	1
1(e)	Value of A = candidate's gradient and value of B = candidate's intercept. The values must not be fractions.	1
	Unit for A is correct (e.g. m^{-1} or cm^{-1} or mm^{-1}) and unit for B is correct (e.g. $\Omega \text{ m}^{-1}$ or $\Omega \text{ cm}^{-1}$ or $\Omega \text{ mm}^{-1}$).	1

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Question	Answer	Marks
2(a)(i)	Value of x to the nearest mm with unit in the range 9.0–11.0 cm.	1
2(a)(ii)	Percentage uncertainty in x based on absolute uncertainty of 2–4 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
2(b)(i)	Value of raw L to the nearest mm with unit and in the range 20.0–30.0 cm.	1
2(b)(ii)	Correct calculation of $\sqrt{L}$.	1
2(b)(iii)	Justification for s.f. in $\sqrt{L}$ linked to s.f. in L .	1
2(c)	Second value of x .	1
	Second value of L .	1
	Quality: Second value of $L >$ first value of L .	1
2(d)(i)	Two values of k calculated correctly.	1
2(d)(ii)	Valid comment consistent with calculated values of k , testing against a criterion stated by the candidate.	1
2(e)(i)	Value of T in the range 1.0–2.0 s.	1
2(e)(ii)	Correct calculation of g with correct consistent unit using second value of k .	1

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Question	Answer	Marks
2(f)(i)	A Too few readings/(only) two readings not enough to draw a (valid) conclusion (not 'not enough for accurate results', 'few readings'). B Difficult to determine x or L_0 or L with reason e.g. parallax error/locating centre of bob/lower curved edge of wooden rod/holding ruler by hand. C Difficult to release two bobs at same instant/time. D Pendulums have different amplitudes/displacements or Two oscillations have different motions so difficult to compare. E Difficult to judge when the two pendulums are exactly in phase/difficult to adjust to the exact length so that the pendulums are in phase/trial and error process needed to identify when length gives same phase. F Difficult to judge start of/end of/complete oscillation. <i>1 mark for each point up to a maximum of 4.</i>	4
2(f)(ii)	A Take more readings <u>and</u> plot a graph or take more readings <u>and</u> compare k values (not 'repeat readings' on its own). B Measure to top and bottom of ball and take average or Take string off and measure on table or Clamp a ruler (vertically). C Improved method of release e.g. card gate release. E Use stop-watch and test for same period for each pendulum. F Video/record/film and view with timer/frame-by-frame. <i>1 mark for each point up to a maximum of 4. There is no marking point labelled D.</i>	4

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GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

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Question	Answer	Marks
1(a)	Value of x in the range 28.0–32.0 cm with unit.	1
	Value of y in the range 45.0–55.0 cm.	1
1(b)	Six sets of readings of x and y (different values) showing the correct trend and without help from the Supervisor scores 5 marks, five sets scores 4 marks etc.	5
	Range: Must include one value of $x \leq 10.0$ cm and one value of $x \geq 50.0$ cm.	1
	Column headings: Each column heading must contain a quantity and a unit where appropriate. The presentation of the quantity and unit must conform to accepted scientific convention e.g. x / m .	1
	Consistency: All raw values of x and y must be given to the nearest mm.	1
1(c)(i)	Axes: Sensible scales must be used, no awkward scales (e.g. 3:10 or fractions). 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.	1
	Plotting of points: All observations in the table must be plotted on the grid. Diameter of plotted points must be $\leq$ half a small square. Points must be plotted to an accuracy of half a small square.	1
	Quality: All points in the table (at least 5) must be plotted on the grid. Trend of points on graph must be positive. All points must be within ± 1.0 cm (to scale on the axis with the y values) of a straight line.	1

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Question	Answer	Marks
1(c)(ii)	Line of best fit: 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. One anomalous point is allowed only if clearly indicated (i.e. circled or labelled) by the candidate. There must be at least 5 points left after the anomalous point is disregarded. Line must not be kinked or thicker than half a small square.	1
1(c)(iii)	Gradient: The hypotenuse of the triangle used must be greater than half the length of the drawn line. Both read-offs must be accurate to half a small square in both the x and y directions. The method of calculation must be correct e.g. not $\Delta x / \Delta y$. The sign of the gradient on the answer line must match the graph.	1
	y-intercept: Correct read-off 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 Intercept read directly from the graph with read-off at $x = 0$ accurate to half a small square.	1
1(d)	Value of A = candidate's gradient and value of B = candidate's intercept. The values must not be fractions.	1
	A has no unit and unit for B correct (m, cm or mm).	1
1(e)	Correct calculation of M with a consistent unit.	1
	Answer on the answer line to 3 significant figures.	1

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Question	Answer	Marks
2(a)(i)	Value of x in the range 6.5–7.5 cm to the nearest mm with unit.	1
2(a)(ii)	Percentage uncertainty in x based on absolute uncertainty in the range 2–4 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
2(b)(i)	Value of T_1 in the range 0.4–1.0 s.	1
	At least two values of nT recorded where $n \geq 5$.	1
2(b)(ii)	Value of T_2 greater than T_1 .	1
2(b)(iii)	Correct calculation of $T_2 - T_1$.	1
2(c)	Second value of x .	1
	Second values of T_1 and T_2 .	1
	Quality: Second value of $ T_2 - T_1 < \text{first value of } T_2 - T_1 $.	1
2(d)(i)	Two values of k calculated correctly.	1
2(d)(ii)	Justification for s.f. in k linked to s.f. in x <u>and</u> $(T_2 - T_1)$.	1
2(d)(iii)	Valid comment consistent with calculated values of k , testing against a criterion stated by the candidate.	1

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Question	Answer	Marks
2(e)(i)	A Too few readings/(only) two readings not enough to draw a (valid) conclusion (not ‘not enough for accurate results’, ‘few readings’). B Problem with attaching spring to magnet e.g. tape not sticky enough, magnet falls from tape or Problems with additional modelling clay falling off magnet. C Difficult to line up magnets (because they repel). D Difficulty setting or measuring x with a reason e.g. holding metre rule by hand/metre rule or magnet moves/metre rule not vertical/parallax error/magnet is tilted so x varies across the width of the magnet/difficult to adjust boss so that x has the constant value. E $(T_2 - T_1)$ is short or Percentage uncertainty in $(T_2 - T_1)$ is large or Difficult to judge start of/end of/complete oscillation. F Others modes of oscillation e.g. magnet swinging or Magnets are attracted/stick to the stand (metal rod) and/or G-clamp/metal table. <i>1 mark for each point up to a maximum of 4.</i>	4

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Question	Answer	Marks
2(e)(ii)	A Take more readings <u>and</u> plot a graph or take more readings <u>and</u> compare k values (not 'repeat readings' on its own). B Better method of attaching magnet to spring system e.g. glue spring to magnet/stickier tape/magnet with hook/attach string or Improved method of adding weight to magnet e.g. use adhesive putty/tape. C Put magnets in a (transparent) tube. D Improved method of measuring x e.g. place a mm grid behind magnets/clamp metre rule/use set square between ruler and bench/plumb-line to check ruler vertical/use a lab jack to raise magnet B/use travelling microscope. E Improved method of timing e.g. video/film/record with timer/view frame-by-frame, fiducial marker at centre of oscillation, force meter attached to springs. F Use wooden/plastic stand/longer wooden rod or Another named method of fixing magnet B to bench e.g. adhesive putty. <i>1 mark for each point up to a maximum of 4.</i>	4

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Question	Answer	Marks
1(a)	Value of x in range 13.0–17.0 cm.	1
1(b)	Evidence of repeat readings of nT with $n \geq 5$.	1
1(c)	Six sets of readings of x and time with correct trend and without help from the Supervisor scores 4 marks, five sets scores 3 marks, etc.	4
	Range: $x_{\min} \leq 5.0$ cm and $x_{\max} \geq 20.0$ cm.	1
	Column headings: Each column heading must contain a quantity, a unit and a separating mark. The presentation of quantity and unit must conform to accepted scientific convention. e.g. T^2/s^2 .	1
	Consistency: All values of x must be given to the nearest 0.1 cm.	1
	Significant figures: All values of x^2 must be given to the same number of s.f. as, or one greater than, the number of s.f. of x as recorded in the table.	1
	Calculation: Values of T^2 calculated correctly.	1
1(d)(i)	Axes: Sensible scales must be used, no awkward scales (e.g. 3:10 or fractions). Scales must be chosen so that the points plotted on the grid 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.	1
	Plotting of points: All observations must be plotted on the grid. Diameter of plotted points must be $\leq$ half a small square. Points must be plotted to an accuracy of half a small square in both x and y directions.	1
	Quality: All points in the table must be plotted (at least 5). Trend of points on graph must be positive. Scatter of points must be no more than $\pm 25 \text{ cm}^2$ (to scale) from a straight line in the x^2 direction.	1

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Question	Answer	Marks
1(d)(ii)	Line of best fit: Judge by the balance of all 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 its full length. One anomalous point is allowed only if clearly indicated (i.e. circled or labelled) by the candidate. There must be at least 5 points left after the anomalous point is disregarded. Line must not be kinked or thicker than half a square.	1
1(d)(iii)	Gradient: The hypotenuse of the triangle used must be greater than half the length of the drawn line. Method of calculation must be correct, e.g. not $\Delta x / \Delta y$. Both read-offs must be accurate to half a small square in both the x and y directions.	1
	y-intercept: Correct read-off from a point on the line substituted into $y = mx + c$ or an equivalent expression. Read-off must be accurate to half a small square in both x and y directions. or Intercept read directly from the graph, with read-off at $x = 0$ accurate to half a small square in the y direction.	1
1(e)	a equal to candidate's gradient and b equal to candidate's intercept. The values must not be fractions.	1
	Unit for a is correct (e.g. s^2m^{-2}) and unit for b is correct (s^2).	1
1(f)	Value for g calculated correctly.	1

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Question	Answer	Marks
2(a)	Value for h to nearest mm and in range 7–13 mm.	1
2(b)	Value for W to nearest 0.1 N and in the range $1.0 \text{ N} \leq W \leq 5.0 \text{ N}$.	1
2(c)(i)	Evidence that d has been measured to find r .	1
2(c)(ii)	Correct calculation of α .	1
2(c)(iii)	Justification based on s.f. in $(r - h)$ and r .	1
2(d)	Raw values for F to nearest 0.1 N with unit.	1
	Evidence of repeat readings of F .	1
2(e)	Percentage uncertainty based on an absolute uncertainty in F of 0.1–0.4 N. 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
2(f)	Values for second W , r and F .	1
	Quality: Second F less than first F .	1
2(g)(i)	Two values of k calculated correctly.	1
2(g)(ii)	Valid comment relating to the calculated values of k , testing against a criterion specified by the candidate.	1

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Question	Answer	Marks
2(h)(i)	A Too few readings/(only) two readings not enough to draw a (valid) conclusion (not 'not enough for accurate results', 'few readings'). B Large percentage uncertainty in h or h is small so large uncertainty in h. C Difficult to measure <u>diameter</u> with reason, e.g. because diameter not clearly defined, edge is tapered. D Difficult to measure F/read newton meter with a reason, e.g. difficult to judge moment when cylinder starts to roll/cylinder moves suddenly/non-zero reading on newton meter when horizontal. E Force applied at different angles for each cylinder/difficult to pull newton meter horizontally. F Large percentage uncertainty in F or values of F small so large uncertainty in F. <i>1 mark for each point up to a maximum of 4.</i>	4
2(h)(ii)	A Take more readings <u>and</u> plot a graph or take more readings <u>and</u> compare k values (not 'repeat readings' on its own). B Use vernier/digital calipers or micrometer. C Improved method of measuring diameter, e.g. measure between set squares/put blocks either side and measure between blocks. D Use system of pulley and weights/sand or Pointer/marker that stays in maximum position on newton meter/use force sensor and data-logger or Video/film/record experiment with newton meter in view. E Method of applying force horizontally, e.g. use longer loop of thread/support newton meter with additional board. F Use e.g. 0–5 N newton meter (not 'more accurate meter'). <i>1 mark for each point up to a maximum of 4.</i>	4

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Question	Answer	Marks
1(a)	Value of T on the answer line in the range 1.0–2.0 s with unit.	1
1(b)	Six sets of readings of n and T (different values) with the correct trend and without help from the Supervisor scores 5 marks, five sets scores 4 marks etc.	5
	Range: n values include $n = 2$ or less and $n = 13$ or more.	1
	Column headings: Each column heading must contain a quantity, a unit where appropriate and a separating mark. The presentation of quantity and unit must conform to accepted scientific convention e.g. T/s , T^2/s^2 and n has no unit.	1
	Consistency: Raw values of time must <u>all</u> be given to the nearest 0.1 s or <u>all</u> to the nearest 0.01 s.	1
	Significant figures: All values of T^2 must be given to the same number of s.f. as (or one more than) the number of s.f. in raw time values.	1
	Calculation: Correct calculation of T^2 .	1
1(c)(i)	Axes: Sensible scales must be used, no awkward scales (e.g. 3:10 or fractions). 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 must be no more than three large squares apart.	1
	Plotting of points: All observations in the table must be plotted on the grid. Diameter of plotted points must be $\leq$ half a small square. Points must be plotted to an accuracy of half a small square.	1
	Quality: All points in the table (at least 5) must be plotted on the grid. Trend of points on graph must be negative. It must be possible to draw a straight line that is within ± 1 (to scale) on the n -axis of <u>all</u> plotted points.	1

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Question	Answer	Marks
1(c)(ii)	Line of best fit: 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. One anomalous point is allowed only if clearly indicated (i.e. circled or labelled) by the candidate. There must be at least 5 points left after the anomalous point is disregarded. Lines must not be kinked or thicker than half a small square.	1
1(c)(iii)	Gradient: The hypotenuse of the triangle used must be greater than half the length of the drawn line. Both read-offs must be accurate to half a small square in both the x and y directions. The method of calculation must be correct e.g. not $\Delta x / \Delta y$. The sign of the gradient on the answer line must match the graph.	1
	y-intercept: Correct read-off 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 Intercept read directly from the graph with read-off at $n = 0$ accurate to half a small square.	1
1(d)	Value of P = candidate's gradient and value of Q = candidate's intercept. The values must not be fractions.	1
	Unit for P is s^2 and unit for Q is s^2.	1
1(e)	Line W is drawn with the same gradient and a larger y-intercept.	1

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Question	Answer	Marks
2(a)(i)	Value(s) of <u>raw</u> α to the nearest degree and final value $< 90^\circ$.	1
	Evidence of repeated α .	1
2(a)(ii)	Percentage uncertainty based on an absolute uncertainty in α in the range 2–5°. 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
2(b)	Value(s) of raw x to the nearest mm with unit.	1
2(c)	Value of $\beta > \alpha$.	1
2(d)(i)	Correct calculation of $(x + y)^2$.	1
2(d)(ii)	Justification for s.f. in $(x + y)^2$ linked to s.f. in $(x + y)$.	1
2(e)	Second value of x .	1
	Second value of β .	1
	Quality: second value of β greater than α and second value of $\beta <$ first value of β .	1
2(f)(i)	Two values of k calculated correctly.	1
2(f)(ii)	Valid comment consistent with the calculated values of k , testing against a criterion stated by the candidate.	1

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Question	Answer	Marks
2(g)(i)	A Too few readings/(only) two readings not enough to draw a (valid) conclusion (not ‘not enough for accurate results’, ‘few readings’). B Difficulty in measuring angle(s) or α or β with a reason e.g. difficult to hold board or protractor steady/board or protractor held by hand/difficult to hold board and protractor at same time. C Difficulty with raising the board e.g. difficult to raise board evenly/jerks/suddenly rises and consequently board shakes causing magnet to move/difficult to change the angle by small increments (idea of sensitivity). D Base of board slides/slips along bench. E Magnet crashes into bench (and could affect strength of magnet). F Difficulty with board surface e.g. surface may not be uniformly smooth/may be uneven. <i>1 mark for each point up to a maximum of 4.</i>	4
2(g)(ii)	A Take more readings <u>and</u> plot a graph or take more readings <u>and</u> compare k values (not ‘repeat readings’ on its own). B Improved method of supporting protractor or board e.g. clamp protractor/clamp board or Detailed method of using trigonometry e.g. measure elevation (o) and length of board (a) calculate $\sin \text{angle} = o / a$ or Film/video/record with protractor in view. C Method described to increase the angle in smaller increments e.g. lab jack support/string attached to board and a pulley with handle. D Method of fixing base of board e.g. adhesive putty/heavy block. E Improved method to protect magnets e.g. place foam around bench/wooden barrier. F Method to provide a smooth surface e.g. named smooth material e.g. glass or valid method e.g. sand board. <i>1 mark for each point up to a maximum of 4.</i>	4

PHYSICS

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Paper 3 Advanced Practical Skills 2

October/November 2019

MARK SCHEME

Maximum Mark: 40

Published

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.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

Cambridge International will not enter into discussions about these mark schemes.

Cambridge International is publishing the mark schemes for the October/November 2019 series for most Cambridge IGCSE™, Cambridge International A and AS Level components and some Cambridge O Level components.

This document consists of **8** printed pages.



Cambridge Assessment
International Education

Generic Marking Principles

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

PUBLISHED**GENERIC MARKING PRINCIPLE 5:**

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

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Question	Answer	Marks
1(a)(i)	Value of x in range 17.0–23.0 cm.	1
1(a)(ii)	Value of L to nearest mm.	1
1(b)	Value of L greater than value in (a)(ii) .	1
1(c)	Six sets of readings of x and L with correct trend and without help from the Supervisor scores four marks, five sets scores three marks, etc.	4
	Range: $x_{\min} \leq 10.0$ cm.	1
	Column headings: Each column heading must contain a quantity and a unit. The presentation of quantity and unit must conform to accepted scientific convention, e.g. x^2 / cm^2 .	1
	Consistency: All values of x and L must be given to the nearest mm.	1
	Significant figures: Number of significant figures for every value of x^2 same as, or one greater than, the number of s.f. of raw x as recorded in table.	1
	Calculation: Values of x^2 calculated correctly.	1

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Question	Answer	Marks
1(d)(i)	Axes: Sensible scales must be used (no awkward scales, e.g. 3:10 or fractions). 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.	1
	Plotting of points: All observations in the table must be plotted on the grid. Diameter of plotted points must be $\leq$ half a small square. Points must be accurate to within half a small square in both x and y directions.	1
	Quality: All points in the table must be plotted (at least five). Scatter of plots must be no more than ± 1 cm (to scale) from a straight line in the L direction. Trend of points on graph must be negative.	1
1(d)(ii)	Line of best fit: Judge by balance of all points on the grid (at least five) about the candidate's line. There must be an even distribution of points either side of the line along the full length. One anomalous point is allowed only if clearly indicated (i.e. circled or labelled) by the candidate. There must be at least five points left after disregarding the anomalous point. Line must not be kinked or thicker than half a small square.	1
1(d)(iii)	Gradient: The hypotenuse of the triangle used must be greater than half the length of the drawn line. Method of calculation must be correct, e.g. not $\Delta x / \Delta y$. Both read-offs must be accurate to half a small square in both the x and y directions. Sign of gradient on answer line must match graph drawn.	1
	y-intercept: Correct read-off from a point on the line substituted into $y = mx + c$ or an equivalent expression. Read-off must be accurate to half a small square in both 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.	1

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Question	Answer	Marks
1(e)	a equal to candidate's gradient and b equal to candidate's intercept. The values must not be fractions.	1
	Unit for a is correct (e.g. cm^{-1}) and unit for b is correct (e.g. cm).	1

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Question	Answer	Marks
2(a)	Value for h_0 to nearest mm and in range 20–200 mm.	1
2(b)(i)	Value for I in range 0.20–0.70 A and obtained without help from the Supervisor.	1
	Value for V in range 0.5–3.5 V.	1
2(b)(ii)	Value for $h < h_0$.	1
2(b)(iii)	Correct calculation of Δh .	1
2(c)	Percentage uncertainty based on an absolute uncertainty in Δh value of 1 or 2 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
2(d)	Correct calculation of T and value given to nearest K.	1
2(e)	Second values of I , V and h .	1
	Quality: Second Δh greater than first Δh .	1
2(f)(i)	Two values of β calculated correctly.	1
2(f)(ii)	Justification based on significant figures in I , V and $T^4 - T_0^4$.	1
2(f)(iii)	Valid comment relating to the calculated values of β , testing against a criterion specified by the candidate.	1

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Question	Answer	Marks
2(g)(i)	A Too few readings/(only) two readings not enough to draw a (valid) conclusion (not 'not enough for accurate results', 'few readings'). B Difficulty measuring h/h_0/height because rule not vertical/not steady. C Large percentage uncertainty in Δh/large uncertainty in Δh because Δh small. D T_0 may vary from stated value (during the experiment). E Meter readings fluctuate. F Expansion may be permanent/doesn't return to h_0. <i>1 mark for each point up to a maximum of 4.</i>	4
2(g)(ii)	A Take more readings <u>and</u> plot a graph or take more readings <u>and</u> compare β values (not 'repeat readings' on its own). B Hold rule (vertically) in clamp. C1 Use longer wooden strip/attach wire closer to pivot. C2 Use larger current/voltage. C3 Use vernier calipers/digital calipers/travelling microscope. D Use a thermometer to measure T_0 at the time the h readings are taken/during experiment. E Clean crocodile clips/contacts with method. F Re-measure h_0 between tests. <i>1 mark for each point up to a maximum of 4.</i>	4