A-LEVEL
PHYSICS
7408/3A

Paper 3 Section A

Mark scheme

June 2019

Version: 1.0 Final

I96A74083A/MS

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from aqa.org.uk

Copyright © 2019 AQA and its licensors. All rights reserved.
AQA retains the copyright on all its publications. However, registered schools/colleges for AQA are permitted to copy material from this booklet for their own internal use, with the following important exception: AQA cannot give permission to schools/colleges to photocopy any material that is acknowledged to a third party even for internal use within the centre.

Physics - Mark scheme instructions to examiners

1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the Examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

2. Emboldening

2.1 In a list of acceptable answers where more than one mark is available 'any **two** from' is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.
2.2 A bold **and** is used to indicate that both parts of the answer are required to award the mark.
2.3 Alternative answers acceptable for a mark are indicated by the use of **or**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

3. Marking points

3.1 Marking of lists

This applies to questions requiring a set number of responses, but for which candidates have provided **extra** responses. The general principle to be followed in such a situation is that 'right + wrong = wrong'.

Each **extra** error / contradiction negates each correct response. So, if the **number of total errors** / contradictions equals or **exceeds the number of marks available** for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by 'Ignore' in the mark scheme) are not penalised.

3.2 Marking procedure for calculations

Full marks can usually be given for a correct numerical answer without working shown unless the question states 'Show your working'. However, if a correct numerical answer can be evaluated from incorrect physics then working will be required. The mark scheme will indicate both this and the credit (if any) that can be allowed for the incorrect approach.

However, if the answer is incorrect, mark(s) can usually be gained by correct substitution / working and this is shown in the 'extra information' column or by each stage of a longer calculation.

A calculation must be followed through to answer in decimal form. An answer in surd form is never acceptable for the final (evaluation) mark in a calculation and will therefore generally be denied one mark.

3.3 Interpretation of 'it'

Answers using the word 'it' should be given credit only if it is clear that the 'it' refers to the correct subject.

3.4 Errors carried forward, consequential marking and arithmetic errors

Allowances for errors carried forward are likely to be restricted to calculation questions and should be shown by the abbreviation ECF or *conseq* in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

3.5 Phonetic spelling

The phonetic spelling of correct scientific terminology should be credited (eg fizix) **unless** there is a possible confusion (eg defraction/refraction) with another technical term.

3.6 Brackets

(…..) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

3.7 Ignore / Insufficient / Do <u>not</u> allow

'Ignore' or 'insufficient' is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

'Do **not** allow' means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.

3.8 Significant figure penalties

Answers to questions in the practical sections (7407/2 – Section A and 7408/3A) should display an appropriate number of significant figures. For non-practical sections, an A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the **final** answer in a calculation to a specified number of significant figures (sf). This will generally be assessed to be the number of sf of the datum with the least number of sf from which the answer is determined. The mark scheme will give the range of sf that are acceptable but this will normally be the sf of the datum (or this sf -1).

An answer in surd form cannot gain the sf mark. An incorrect calculation **following some working** can gain the sf mark. For a question beginning with the command word 'Show that…', the answer should be quoted to **one more** sf than the sf quoted in the question eg 'Show that X is equal to about 2.1 cm' –

answer should be quoted to 3 sf. An answer to 1 sf will not normally be acceptable, unless the answer is an integer eg a number of objects. In non-practical sections, the need for a consideration will be indicated in the question by the use of 'Give your answer to an appropriate number of significant figures'.

3.9 Unit penalties

An A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the correct unit for the answer to a calculation. The need for a unit to be quoted will be indicated in the question by the use of 'State an appropriate SI unit for your answer'. Unit answers will be expected to appear in the most commonly agreed form for the calculation concerned; strings of fundamental (base) units would not. For example, 1 tesla and 1 Wb m^{-2} would both be acceptable units for magnetic flux density but 1 kg m^2 s^{-2} A^{-1} would not.

3.10 Level of response marking instructions

Level of response mark schemes are broken down into three levels, each of which has a descriptor. The descriptor for the level shows the average performance for the level. There are two marks in each level.

Before you apply the mark scheme to a student's answer read through the answer and annotate it (as instructed) to show the qualities that are being looked for. You can then apply the mark scheme.

Determining a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the descriptor for that level. The descriptor for the level indicates the different qualities that might be seen in the student's answer for that level. If it meets the lowest level then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer. With practice and familiarity you will find that for better answers you will be able to quickly skip through the lower levels of the mark scheme.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level. i.e. if the response is predominantly level 2 with a small amount of level 3 material it would be placed in level 2.

The exemplar materials used during standardisation will help you to determine the appropriate level. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the example to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the example.

You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the indicative content to reach the highest level of the mark scheme

An answer which contains nothing of relevance to the question must be awarded no marks.

Question	Answers	Additional Comments/Guidelines	Mark
01.1	$_1$✓ idea of **maximising distance** use tongs / tweezers / handling tool (when handling source to keep as far away from source as possible) OR keep at least 2 metres away (if observing) $_2$✓ idea of **limiting exposure time during** experiment remove source from lab / room when not in use / after experiment OR idea of put / replace / keep source in a castle / container when not in use / in the open / after experiment or wtte $_3$✓ is about **shielding** using a named absorber stand behind a lead absorber / screen (when source is in the open) $_4$✓ is safe use of source when removed from castle never point (open end of) the source at anyone / at yourself OR do not look directly at / look into the source $_5$✓ is about **good practice** read local rules (about the use of radioactive sources) / OR read / post warning / notice on the door	award 1 mark for each valid procedure (unless contradicted) do not award more than 1 mark for safety procedure 1 and do not award more than 1 mark for safety procedure 2 do **not** credit the same marking point for **different** do not award more than 1 mark for safety procedure 1 procedures for $_1$✓ treat as neutral: 'keep source at arm's length / far away' / 'use pliers' / don't go close (to the source) for $_2$✓ do not insist on 'lead' treat as neutral: 'use a lead container' treat as neutral: 'limit time of exposure' / 'work as quickly as possible' / 'don't keep source out of box for too long' / 'keep source sealed' for $_3$✓ accept aluminium or steel for lead; use of lead apron for $_4$✓ accept 'avoid eyes' treat as neutral: 'avoid direct contact' / 'don't touch source' / 'always point source at ground' for $_5$✓ accept 'report any damage to a source' treat as neutral: 'use safety screen' / 'don't stand in front' / 'don't ingest / swallow' / 'wash hands after use' / 'wear safety glasses / goggles / gloves / lab coats'/ 'use film badge' no credit for procedures that are the responsibility of the teacher / radiation protection adviser, eg 'obtained signed consent form'	AO2-1g = MAX 2

01.2	5 ✓	correct answer only	AO3-1a = 1

01.3	**A** OR $^{222}_{86}$Rn / radon 222 / Rn 222 ✓ **B** OR $^{218}_{84}$Po / polonium 218 / Po 218 ✓ **I** OR $^{210}_{82}$Pb / lead 210 / Pb 210 ✓	if candidates have provided more than 3 responses, each extra error / contradiction negates one correct response; if there are 3 or more errors / contradictions, award no marks answers may be given **in any order** accept unnamed isotope with correct *A*, *Z* eg $^{222}_{86}$X eg while the suggestion that A, B and I are correct earns 3 the suggestion that A, B, I and J are correct earns 3 – 1 = 2	AO3-1a = 3

01.4	suitable procedures to eliminate systematic error are: remove (all radioactive) source(s) (from the room) OR measure A_b before the source is present / in another room OR put source in (lead) castle / (lead) container / behind a (lead) absorber $_1$✓ zero / reset the counter AND/OR stopwatch (before use) OR check the counter AND/OR stopwatch has no zero error $_2$✓ measure A_b on same day as experiment is carried out $_3$✓ measure A_b in same room / location / area as that where experiment is to be carried out $_4$✓ suitable procedure to reduce percentage uncertainty in A_b is: use long(er) (integration) time / prolonged time OR (total of) at least 100 s $_5$✓	do not insist on references to systematic or random error but give no credit for **explicit** talk-out eg 'use a long integration time to eliminate systematic error' for $_1$✓ treat as neutral: 'measure A_b with no source near' / 'check source is shielded / far away / out of range / sealed' / 'in another area' / 'point detector away from the source (or vice-versa)' / 'don't point source at counter' / 'put detector behind source' for $_2$✓ treat as neutral: 'zero / reset the equipment (before use)' / 'zero the detector' for $_3$✓ treat as neutral: 'measure A_b after experiment to double-check' for $_4$✓ treat as neutral: / 'keep detector in the same position' / 'measure A_b in different positions' for $_5$✓ accept idea of a suggested total time, taking account of repeats, exceeding 100 s (eg 10 repeated 10 s counts and 1 single 100 s single count amount to the same thing) treat as neutral: 'repeat and average' ignore anomalous results' / 'use room with high background count / record large reading' / 'use more than one detector'	AO2-1g = MAX 3

01.5	use of $5.5\ \text{MeV}$ shown by **working** on **Figure 4** $_1$✓ minimum thickness MAX 3sf that rounds to $12\ \text{mm}$ $_2$✓$_3$✓ OR minimum thickness MAX 3sf that rounds to $11\ \text{mm}$ / MAX 3sf that rounds to $13\ \text{mm}$ $_{23}$✓	for $_1$✓ use of $5.5\ \text{MeV}$ can be inferred from **Figure 4** as a (horizontal) **line**, **a mark** on the vertical axis or **a mark** on the curve / intersection between curve and a vertical line, **above** 5 MeV **and below** 6 MeV; a single line / mark between 5 and 6 MeV with no subsequent working can score $_1$✓ any line does not have to be ruled or perfectly parallel to the grid line; allow a cross or a small blob as the mark on the curve; do not insist on seeing a vertical line if more than one line is drawn / mark is made then mark as per scheme if a clear decision has been made about which read-off has been used to provide the result for the **thickness**; allow only one **thickness** given as final answer $_2$✓$_3$✓ OR $_{23}$✓ can be earned without any working on the grid / other intermediate working	AO3-1a = 1 AO3-1b = 2
	OR use of $7.8\ \text{MeV}$ shown by working on **Figure 4** AND minimum thickness is 16, 17 or $18\ \text{mm}$ $_{123}$✓	for $_{123}$✓ use of of $7.8\ \text{MeV}$ can be inferred from **Figure 4** as a line, mark on axis / curve etc above 7 MeV and below 8 MeV; accept MAX 3 sf result that rounds to 16, 17 or $18\ \text{mm}$	

01.6	$d = \sqrt{k} \times \frac{1}{\sqrt{A}} - e$ OR $d = \sqrt{k} \times \sqrt{\frac{1}{A}} - e$ OR $d = \sqrt{\frac{k}{A}} - e$ seen $_1$✓ **states** $\sqrt{k}$ = gradient OR k = gradient^2 $_2$✓ gradient from Δd divided by $\Delta \frac{1}{\sqrt{A}}$ with $\Delta \frac{1}{\sqrt{A}} \geq 0.5$ $_3$✓ k minimum 2 sf in range $1.7(0) \times 10^5$ to $1.9(5) \times 10^5$ $_4$✓ unit for k = $\text{mm}^2\ \text{Bq}$ or $\text{mm}^2\ \text{s}^{-1}$ $_5$✓ for **statement** that k = gradient mark as follows: for $d = k \times \frac{1}{\sqrt{A}} - e$ **AND** k = gradient $_{12}$✓ = 1 MAX; award $_3$✓ as above $_{45}$✓ = 1MAX ecf for the following: k in range 410 to 450 or 2 sf 4.1 to 4.5 $\times 10^2\ \text{mm Bq}^{0.5}$ or $\text{mm s}^{-0.5}$ OR k in range 0.41(0) to 0.45(0) $\text{m Bq}^{0.5}$ or $\text{m s}^{-0.5}$ OR k in range 41.(0) to 45(.0) $\text{cm Bq}^{0.5}$ or $\text{cm s}^{-0.5}$	for $_1$✓ d must be the subject; allow obvious slips, eg D for d for $_2$✓ allow $\sqrt{k} = m$ if $y = mx + c$ is quoted so inference that $\sqrt{k}$ = gradient is clear; this mark is for **explaining** the step and **not** for performing the calculation for $_3$✓ the mark is for the process, not the result; evidence of acceptable steps on grid with plausible result are enough; no credit if false origin missed allow working subsumed into calculation of k for $_4$✓ gradient based on d in mm (expected = $433\ \text{mm Bq}^{0.5}$) POT 10^5 required for $_5$✓ the unit given for k must be consistent with the POT of the result for k / gradient^2 order not important Bq mm^2 is acceptable; do not accept incorrect symbol, eg bq for Bq otherwise: if for $_4$✓ gradient based on d in m (expected $\approx 0.43\ \text{m Bq}^{0.5}$) k in range $0.17(0)$ to $0.19(5)$ then for $_5$✓ $\text{m}^2\ \text{Bq}$ or $\text{m}^2\ \text{s}^{-1}$ if for $_4$✓ gradient based on d in cm (expected $\approx 43\ \text{cm Bq}^{0.5}$) k in range $1.7(0) \times 10^3$ to $1.9(5) \times 10^3$ then for $_5$✓ $\text{cm}^2\ \text{Bq}$ or $\text{cm}^2\ \text{s}^{-1}$	AO2-1d = 2 AO2-1h = 1 AO3-1b = 2

01.7	second mark ($_2$✓) **is contingent on** award of first ($_1$✓) an unsupported answer or an answer obtained by scale drawing or by extrapolation off the grid score zero attempts to find *e* by <u>calculation</u> by any valid method using gradient or *k* with all data **correctly** substituted in **their** expression; allow use of *y* for *d*, *x* for $\frac{1}{\sqrt{A}}$, *m* for $\sqrt{k}$ and *c* for *e*; attempts to solve for *e* $_1$✓ ≥ 2 sf result in range ≥ 28(.0) and ≤ 32(.0) (mm) $_2$✓	for $_1$✓ use of *y* = *mx* + *c* with recognisable data **correctly** substituted, eg $e =$ their gradient $\times \frac{1}{\sqrt{A}} - d$ with substitution of their gradient and values of values of *d* and $\frac{1}{\sqrt{A}}$ from a point on the line from **Figure 6** OR $e = \sqrt{k} \times \frac{1}{\sqrt{A}} - d$ with substitution of their *k* etc OR (–)*e* = gradient × horizontal intercept, with substitution of their gradient and horizontal intercept ignore POT errors in their gradient / their *k*; allow mixed units and read-off errors of 1 small square for $_2$✓ answer in range only (no ecf from 01.6) allow negative answer	AO2-1d = 1 AO3-1b = 1
Total			**19**

Question	Answers	Additional Comments/Guidelines	Mark
02.1	general procedure • collect water for a measured time; • **divide** measured / calculated volume by time to determine rate $_1$✓	**static** volume should be measured **after timing**, eg reject 'measure time to fill cylinder' **or $_1$✓= 0** accept 'find *V* for different *t*, plot *V* against *t*, gradient = *Q*' but not if by continuous flow method	AO2-1g = 1
	names 2 suitable instruments $_2$✓	for time use <u>stopwatch</u> or <u>stop</u>clock; treat as neutral: 'timer' or 'light gate / data logger' for volume use <u>measuring cylinder</u> / graduated beaker; treat as neutral: 'measuring beaker' / 'burette' OR for mass use <u>balance</u>; use of $V = \frac{m}{\rho}$ (any subject) condone 'volume of 1 g is 1 cm^3'; reject 'weigh'/'weighed'	AO2-1g = 1
	method to reduce uncertainty in volume $_3$✓	read water level at <u>bottom of the meniscus</u> (or wtte or allow sketch); don't penalise further use of 'beaker' treat as neutral: 'dry cylinder before use' OR procedure to avoid systematic error in determining mass, eg tare / reset / zero the balance with empty beaker on pan / find mass of beaker empty and subtract from mass of beaker plus water; don't penalise further use of 'weigh'/ 'scales' allow 'use balance on a <u>horizontal</u> surface'	AO2-1c = MAX 2
	method to reduce uncertainty in time $_4$✓	ensure stopwatch is zeroed / reset before use	
	added detail $_5$✓$_6$✓$_7$✓	collect large(r) <u>volume</u> / for long(er) <u>time</u> / ≥ 60 s $_5$✓ this reduces <u>percentage</u> / <u>fractional</u> uncertainty $_6$✓ read at <u>eye level</u> or wtte, to reduce <u>parallax</u> $_7$✓	

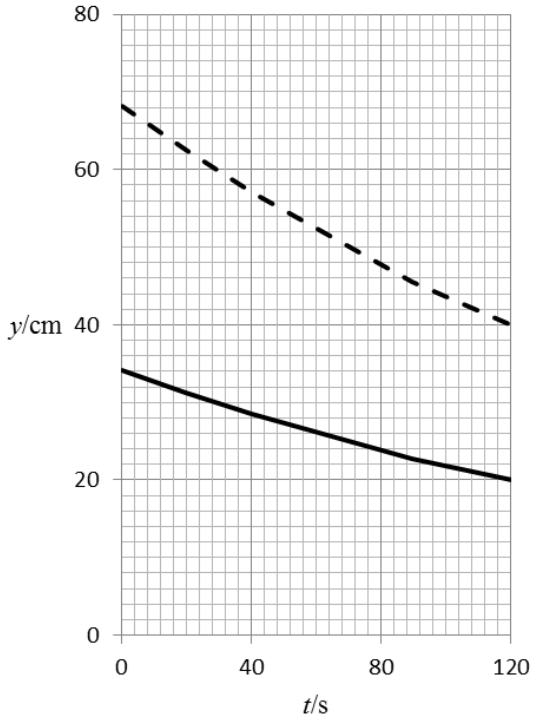
02.2	sensible mark identifying second box indicating ($\mathrm{N\ m^{-2}\ s}$) only	**auto marked question**	AO3-1a = 1

02.3	19.8% (from $4 \times 2.9\% + 1.8\% + 6.4\%$) earns both marks ✓✓	don't insist on seeing '%' unless 0.198 etc allow final answer rounded to 20% allow 1 mark for 0.198 or 0.20 but reject 1 sf 0.2 for incorrect answer the following can earn one mark: (percentage uncertainty in d =) $4 \times 2.9\%$ / 11.6% / 12% seen in working but wrong final answer OR missing $\times$ 4 eg $2.9\% + 1.8\% + 6.4\% = 11(.1)\%$ OR incorrect multiplier applied to 2.9 eg $2 \times 2.9\%$ OR with $\times$ 4 applied wrongly eg 2.9 + (1.8 x 4) + 6.4 = 16.5 % or 17 % / 2.9 + 1.8 + (6.4 x 4) = 30(.3) %	AO3-1b = 2

02.4	appropriate use (ie close to and parallel with the vertical side of the tube, but not necessarily in contact with the tube) of: a metre ruler made vertical using a set-square in <u>contact with the bench</u> / <u>floor</u> / (flat) <u>surface</u> OR a plumb line / weight on <u>vertical</u> string (reject 'pendulum') OR a spirit level ✓	the mark can be awarded for a convincing sketch, eg use of a very large set square without ruler accept 'tri-square' for set square the only acceptable horizontal reference is the bench: don't allow use of horizontal T, eg set square placed on T even if sketch looks convincing no credit for attempt to show graduations on tube are horizontal / use of 'protractor' for set-square / 'each side of meniscus at same level' / use of clamp stand rod or wall as vertical reference	AO2-1g = 1

02.5	attempted use of $y = y_0\,e^{-\lambda\Delta t}$ with substitution of values of y, y_0 and Δt obtained **directly** from **Figure 10** / plausible values obtained from **Figure 13** OR tangent drawn on **Figure 10** to find $\frac{dy}{dt}$; use of $\frac{dy}{dt} = (-)\lambda \times y^*$ and y^* is where tangent meets the curve $_1$✓ valid calculation **seen** leading to a result for λ that rounds to 3 sf in range 4.45 to 4.55×10^{-3} (s^{-1}); award if seen in body of answer $_2$✓	for $_1$✓ do not penalise y / y_0 interchanged, read off errors, manipulation errors / $\Delta t = t$ / t_0 / $\frac{t}{t_0}$ or use of incorrect symbols eg A, N for y; no ecf for $_2$✓ allow use of **Figure 13** $y_0 = 60.0$ cm, $y = 52.2$ cm; $\Delta t = 60 - 29 = 31$ s $52.2 = 60\,e^{-31\lambda}$; $\therefore \lambda = 4.49 \times 10^{-3}$ s^{-1} if the intermediate step is seen, eg $\lambda = \frac{1}{\Delta t} \times \ln\left(\frac{y_0}{y}\right) = \frac{1}{31} \times \ln\left(\frac{60}{52.2}\right)$ accept 'log' for 'ln' no credit allowed for reverse-working method in a 'Show that' problem	AO2-1h = 1 AO3-1b = 1
	variation on use of use of $y = y_0\,e^{-\lambda\Delta t}$ for $_1$✓: λ can be found if points t_1, y_1 and t_2, y_2 are used and the values substituted into $\frac{y_1}{e^{-\lambda t_1}} = \frac{y_2}{e^{-\lambda t_2}}$; if this approach is used substitute the data into $\lambda = \frac{1}{\Delta t} \times \ln\left(\frac{y_0}{y}\right)$ to confirm that the result for λ is correct before awarding $_2$✓	no credit for assuming straight line and $y = mx + c$, measuring the gradient then by determining the equation of the line or by using $m = \frac{y_2 - y_1}{t_2 - t_1}$ determines the half life; finds λ from $\frac{\ln 2}{\text{half life}}$ no credit for common error $\lambda = \text{gradient} \times 2$ for $_2$✓ look for any answer in the body that deserves credit (for a 'Show that' we can overlook truncation in the value given on the answer line)	

<table>
<tr>
<td>02.6</td>
<td>use of $T_{½} = \frac{\ln 2}{\lambda}$ OR $\frac{\ln 0.5}{-\lambda}$ with substitution of recognisable λ;
evaluated to ≥ 2 sf in range $140\,\text{s}$ to $170\,\text{s}$ ✓</td>
<td>calculation can have any subject;
accept use of 2 sf $\lambda = 4.5 \times 10^{-3}$ usually leading to 154 but allow correctly truncated to 150 or 1.5×10^{2}</td>
<td>AO3-1a = 1</td>
</tr>
<tr>
<td>02.7</td>
<td>(mostly) continuous line drawn on Figure 13;
below dashed line and with negative gradient between t = 0 and t = 120;
do not penalise linear line or shaky / thick / hairy line or slight discontinuities; accept ≈ horizontal after 100 s ₁✓

line passes through:
<table><tr><th rowspan="2">t/s</th><th colspan="2">y/cm</th></tr><tr><th>min</th><th>max</th></tr><tr><td>0</td><td>33</td><td>35</td></tr></table>
AND through EITHER of
<table><tr><th rowspan="2">t/s</th><th colspan="2">y/cm</th></tr><tr><th>min</th><th>max</th></tr><tr><td>60</td><td>24</td><td>28</td></tr><tr><td>120</td><td>17</td><td>23</td></tr></table>₂✓</td>
<td>
</td>
<td>AO2-1d = 2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>13</td>
</tr>
</table>

Question	Answers	Additional Comments/Guidelines	Mark
03.1	f (from $\frac{1}{T}$) in range 61 ± 1 Hz $_1$✓$_2$✓ OR 61 ± 3 Hz $_{12}$✓ maximum 1 mark for POT error OR incorrect rounding no credit for 1 sf; treat 60 as 2 sf unless clearly rounded to 6×10^1	for $_1$✓$_2$✓ **require ≥ 2 sf** that rounds to not less than 60 and not more than 62 for $_{12}$✓ **require ≥ 2 sf** that rounds to not less than 58 but less than 60 OR for $_{12}$✓ **require ≥ 2 sf** that rounds to more than 62 but not more than 64 if incorrect rounding leads to 60 treat this as 1 sf and give no credit use of $\frac{1}{T}$ does not have to be seen; marks are for final answer seen	AO3-1a = 2
03.2	(figures) 804 and 226 seen in working $_1$✓ λ = difference between their readings $\times$ 2; given to nearest mm; expect 1.156 (m) OR to nearest cm; expect 1.16 (m) $_2$✓	for $_1$✓ 578 is not enough for $_2$✓ range is based on x = $(804 - 226 =)\ 578 \pm 2$ mm; give no credit for POT errors eg 115.6 / 116 etc accept 1156 mm etc if unit on answer line is amended	AO3-1b = 2
03.3	c correctly evaluated to ≥ 2 sf from their $f \times$ their λ ✓	substituted data may be from 03.1/2 final answers or unrounded (intermediate) data from working expected answer = $61 \times 0.578 \times 2 = 70.5$ m s^{-1}	AO2-1d = 1

03.4	μ correct to 2 sf based on their *f* and their λ earns both marks $_1$✓$_2$✓ for incorrect / missing μ EITHER use of $c = \sqrt{\frac{T}{\mu}}$ OR use of $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ $_{12}$✓	for $_1$✓ their value of μ can be given to ≥ 2 sf but must agree with $\frac{0.5 \times g}{(\text{their } f \times \lambda)^2}$ OR $\frac{0.5 \times g}{(\text{their } c)^2}$ **when rounded to 2 sf**; use of g = 9.81 or 9.8 only; no ecf for mixed units expected answer $\mu = 9.9 \times 10^{-4}$ (kg m^{-1}): be wary of which approach has been taken by the candidate for $_{12}$✓ 'use of' means allow **either** rearranges so that μ is the subject eg $\mu = \frac{T}{c^2}$ (accept $\mu = \frac{mg}{c^2}, \frac{T}{c^2} = \mu$ etc) **or** substitution of all relevant data including their *c* into a correct expression with μ as the only unknown for T allow 4.9 / 4.91 / 4.905 (accept 0.5 × 9.81 or 0.5 × 9.8); allow mixed units; allow 0.5g OR 'use of' means allow **either** rearranges to $\mu = \frac{T}{(2 \times l \times f)^2}$ OR $\frac{T}{4 \times l^2 \times f^2}$ **or** substitution of all relevant data including their l and f leaving μ as the unknown; allow sub of λ for $2l$ watch for possible error $\lambda = L$	AO2-1d = 2

03.5	0.71 (mm) ✓	only answer that gets mark	AO3-1b = 1

03.6	ANY TWO FROM repeat readings at different points along the rod and calculate an average / mean $_1$✓ repeat readings in different directions (perpendicular to the rod) and calculate an average / mean $_2$✓ reject / discard anomalous readings before calculating an average / mean $_3$✓ award $_{123}$✓= 1 MAX for checking at different points / in different directions to confirm that the rod is uniform / that there are no anomalies	allow 'cylinder' / 'wire' etc for rod for $_1$✓ $_2$✓ and $_3$✓ averaging idea only needs to be seen once; if averaging idea missing then allow 'repeat at different points and in different directions, then remove anomalies' $_{123}$✓= 1 MAX if 'calculate' is not seen allow 'work out' / /'determine' / 'compute'; anything that sounds like a mathematical process is ok; 'find' / 'obtain' / 'take' / 'do an average' are just ok; 'get' is not ok for $_1$✓ allow repeat at 'different positions' / 'down / along the rod' for $_2$✓ allow (repeat in different directions) 'around the rod' / 'different orientations' / 'angles' / 'planes' / 'sides' for $_3$✓ allow 'ignore anomalies'; 'outlier' = 'anomaly' reject 'calculate an average to eliminate effect of anomalies' treat as neutral: 'turn the wheel to close the callipers' / suggestions about calibration treat as neutral: 'zero callipers before use' this is a procedure to eliminate a source of systematic error	AO2-1g = MAX 2

03.7	(for use of expected 0.71) $\rho = 8.9(41) \times 10^{3}$ (kg m^{-3}) OR (for use of 0.53) $\rho = 1.6(05) \times 10^{4}$ (kg m^{-3}) OR $\rho = \frac{4.51 \times 10^{-3}}{(\text{their } d \text{ from } 03.5)^2}$ $_{123}$✓✓✓ OR attempts to use μ OR $3.5(4) \times 10^{-3}$ divided by their (recognisable) cross-sectional area $_{1}$✓ AND/OR evidence showing cross-sectional area = $\frac{\pi d^2}{4}$ using their d from 03.5 (allow πr^2 using their d) $_{2}$✓	correct answer scores $_{123}$✓✓✓ for $_{123}$✓✓✓ allow an answer that rounds to the correct 2 sf value sample results for expected d d/mm: 0.71; 0.53 A/m^2: 3.96×10^{-7}; 2.21×10^{-7} ρ/kg m^{-3}: $8.9(41) \times 10^{3}$; $1.6(05) \times 10^{4}$ for $_{1}$✓ accept use of symbols, eg $\rho = \frac{\mu}{A}$ / $= \frac{3.54 \times 10^{-3}}{A(\times 1)}$ / $= \frac{4 \times \mu}{\pi \times d^2}$ / $= \frac{4 \times 3.54 \times 10^{-3}}{\pi \times d^2 (\times 1)}$ $= \frac{3.54 \times 10^{-3}}{\pi \times r^2 (\times 1)}$ for $_{2}$✓ expect correct value of A seen or correct values of A or d in working, eg $\rho = \frac{3.54 \times 10^{-3}}{3.96 \times 10^{-7} (\times 1)}$ / $= \frac{4 \times 3.54 \times 10^{-3}}{\pi \times (0.71 \times 10^{-3})^2 \times (1)}$ accept values ≥ 2 sf for A; allow ecf d and don't penalise POT error in A or d (eg missing 10^{-7}, 10^{-3})	AO3-1a = 1 / AO2-1h = 2

Total			**13**