A-level
PHYSICS
7408/3A

Paper 3 Section A

Mark scheme

June 2025

Version: 1.0 Final

256A7408/3A/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 Examiner.

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.

No student should be disadvantaged on the basis of their gender identity and/or how they refer to the gender identity of others in their exam responses.

A consistent use of 'they/them' as a singular and pronouns beyond 'she/her' or 'he/him' will be credited in exam responses in line with existing mark scheme criteria.

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

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 error/contradiction negates each correct response. So, if the number of 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.

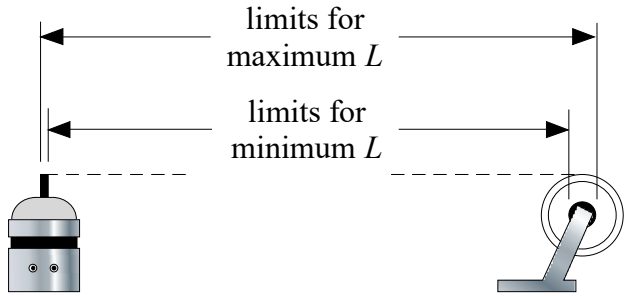
When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level, ie 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/Guidance	Mark	AO
01.1	mass per unit length **of string** OWTTE $_1$✓	**quantitative properties only** answers may be in either order for $_1$✓ condone minor slip 'wire'; condone 'μ' **of string**; 'type of string' / 'same string' are neutral	2	AO1
	length (of string) between vibration generator and pulley $_2$✓	for $_2$✓ accept 'distance between vibration generator and pulley' / 'length of horizontal (part of) string;		
	acceptable limits for defining L in **Figure 1**:  	allow clear annotation to **Figure 1** to **correctly** identify dimension (correct by eye): allow use of a symbol, eg L condone 'amplitude of supply output voltage' / 'output voltage' or WTTE 'ac frequency' (or WTTE) / 'total (suspended) mass' / 'length of vibrating section (of string)' / 'diameter of string' (or WTTE) / 'amount of string between generator and pulley'/ 'temperature of string' / 'positions of generator etc' are neutral		

Question	Answers	Additional comments/Guidance	Mark	AO
01.2	m has a maximum range of 170 g. ✓	CAO	1	AO3

Question	Answers	Additional comments/Guidance	Mark	AO
01.3	V_{peak} in range $18(.0)$ to $19(.0)$ (V) OR calculates V_{rms} using $\frac{\text{their } V_{peak}}{\sqrt{2}}$ $_1$✓ V_{rms} in range 13.0 to 13.2 (V) $_2$✓	for $_1$✓ allow $V_{rms} = 0.71 \times$ their V_{peak} etc; allow $V_{peak\ to\ peak}$ in range $36(.0)$ to $38(.0)$ (V) OR $V_{rms} = \frac{\text{their } V_{peak\ to\ peak}}{2\sqrt{2}}$ allow V_{rms} **correct** in cm, ie $\frac{3.7 \pm 0.1}{\sqrt{2}}$ OR $\frac{7.4 \pm 0.2}{2\sqrt{2}}$ for $_2$✓ max 4 sf; condone 4 sf rounding to 3 sf in range do not accept 2 sf 13 (V)	2	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
01.4	T_{100} in range 104 to 107 (ms) ✓	period must be expressed in units of time; allow 0.104 to 0.107 **s** if answer line amended	1	AO3

Question	Answers	Additional comments/Guidance	Mark	AO
01.5	determines T_{200} OR f_{200} AND attempts to compare T_{200} with T_{100} (their **01.4**) OR attempts to compare f_{200} with f_{100} (based on their **01.4**) 1✓ expected pairs of values: $T_{100} = 105.4$ ms; $T_{200} = 74.5$ ms $f_{100} = 9.49$ Hz; $f_{200} = 13.4$ Hz $T_{100} = 5.30$ cm; $T_{200} = 3.73$ cm compares $\frac{\text{their } T_{100}}{\text{their } T_{200}}$ OR $\frac{\text{their } f_{200}}{\text{their } f_{100}}$ to $\sqrt{2}$ OWTTE AND makes a reasoned judgement (to show if their evidence is consistent with doubling m) 2✓	for 1✓ their T_{200} in range 73.5 to 75.6 ms OR f_{200} in range 13.2 to 13.6 Hz; condone use of T_{100} and T_{200} in cm OR in div; ignore POT but must be consistent between values for $T_{100/200}$ or $f_{100/200}$; allow **any** quantitative comparison; condone a qualitative comparison award 2✓ as follows: states **Figure 2** is the expected result with $\frac{\text{their } T_{100}}{\text{their } T_{200}} \geq 1.34$ AND ≤ 1.48 (OR 1.4) etc OR states **Figure 2** is **not** the expected result with $\frac{\text{their } T_{100}}{\text{their } T_{200}} < 1.13$ OR > 1.69 ; otherwise accept either conclusion OR 'cannot tell'	2	AO3
Total			**8**	

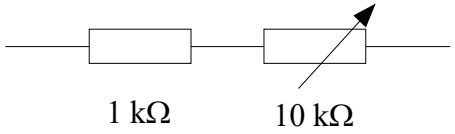
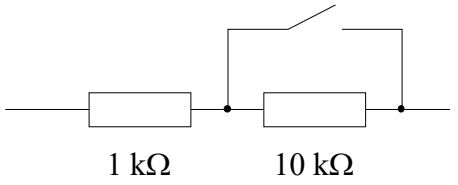
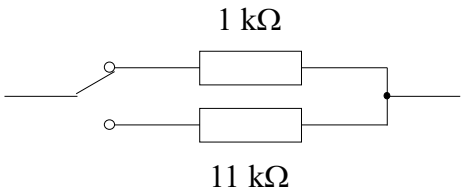
Question	Answers	Additional comments/Guidance	Mark	AO
02.1	(measuring $20T$) (idea of) reduces the **effect of** random error (on T) OR reduces the **percentage** uncertainty ✓	allow (idea of) 'reducing **the effect** of uncertainty due to 'stop-start error' / 'human reactions' / 'human error'; accept 'to improve precision' / 'to reduce relative error' / reduces the **percentage** error; condone 'reduces the uncertainty in T ' 'to calculate an average' is neutral; to reduce 'uncertainty' / 'measurement error' / 'human error' / 'human reactions' / 'stop-start error' are neutral 'easier to measure' / 'improve accuracy' / comments about systematic error are neutral	1	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	(repeating the ($20T$) measurements) (idea of) a check for / enables the detection of / elimination of anomalies (in $20T$) ✓	allow 'to avoid miscounting cycles'; accept 'to improve accuracy' / 'to reduce statistical error' / 'account for systematic error' 'to reduce the effect of anomalies' / 'to calculate an average' are neutral; 'to reduce (effect of) uncertainty' / 'measurement error' / 'human error' are neutral 'improve precision' / comments about random error are neutral	1	AO1

Question	Answers	Additional comments/Guidance	Mark	AO
02.3	average $(20)T$ OR uncertainty in $(20)T$ 1✓	for 1✓ average $20T = 19.2$ (s) (use evidence of calculator value 19.196 to confirm that all 5 sets were used) OR uncertainty in $20T = 0.27$ OR $\frac{19.45 - 18.91}{2}$; allow $19.45 - 19.2(0)$ OR $19.2(0) - 18.91$ average $T = 0.96$ (s) (calculator value 0.9598) OR uncertainty in $T = 0.0135 / 0.014$ (s) OR $\frac{0.973 - 0.946}{2}$; allow $0.973 - 0.96$ OR $0.96 - 0.946$	2	AO2
	percentage uncertainty **based on a correct method** $= 1.4\ \%$ 2✓	for 2✓ accept any > 2 sf that rounds to 1.4%; condone max 4 sf; do **not** allow 0.014		

Question	Answers	Additional comments/Guidance	Mark	AO
02.4	gradient evaluated from ΔT divided by ΔR_2 with $\Delta R_2 \geq 6\ \text{k}\Omega$; OR evidence of valid simultaneous equations with full substitution using read-offs for T and R_2 with $\Delta R_2 \geq 6\ \text{k}\Omega$ $_1$✓ attempts to determine C by a valid method $_2$✓ C in range 3.8×10^{-5} to 4.1×10^{-5} (F) $_3$✓ attempts to determine R_1 by a valid method $_4$✓ R_1 in range 2.2 to 2.5×10^4 (Ω) $_5$✓	$_1$✓ is for the process, not the result allow **one** read off error; allow POT error in substituted data expect gradient $\approx 5.5 \times 10^{-5}$ (s Ω^{-1}); award $_2$✓$_3$✓ for C in range with correct POT; $_2$✓ is for the process, not the result: see page 12 for $_3$✓ allow ECF for use of their R_1 ; no ECF for POT OR a calculation error in gradient award $_4$✓$_5$✓ for R_1 in range with correct POT; $_4$✓ is for the process, not the result etc; do **not** allow working off grid to determine R_1 for $_5$✓ allow ECF for use of their C or their gradient min 2 sf for $_3$✓ and $_5$✓; allow ≥ 3 sf rounding to 2 sf in range; don't penalise twice for results based on simultaneous equations with R_2 values in $\text{k}\Omega$	5	AO2

Question	Additional comments/Guidelines for $_2$✓	Additional comments/Guidelines for $_4$✓
02.4	$C = \dfrac{\text{their gradient}}{2 \times \ln 2}$ OR $C = \dfrac{\text{their gradient}}{\ln 4}$ OR $C = \dfrac{\text{their } \Delta T}{2 \times \ln 2 \times \text{their } \Delta R_2}$ OR correct manipulation of valid simultaneous equations OR $C = \dfrac{\text{their } T}{\ln 2 \times (\text{their } R_1 + 2(\text{their } R_2))}$ (where their R_1 has been found by a method not involving C; their T and their R_2 are corresponding values read-off **Figure 4**)	$R_1 = \dfrac{2 \times \text{their vertical intercept}}{\text{their gradient}}$ OR $R_1 = \dfrac{\text{their vertical intercept}}{\ln 2 \times \text{their } C}$ OR $R_1 = \dfrac{\text{their } T}{\ln 2 \times \text{their } C} - 2 \times \text{their } R_2$ (where their T and their R_2 are corresponding values read-off **Figure 4**) OR correct manipulation of valid simultaneous equations OR $R_1 = \dfrac{T_P R_{2Q} - T_Q R_{2P}}{T_Q - T_P}$ (based on read-offs from **Figure** 4 where their R_{2Q} is their value of R_2 at time T_Q etc)

Question	Answers	Additional comments/Guidance	Mark	AO
02.5	marks can be awarded for suitable sketches up to $_{12}$✓✓ for identifying that their R_2 should • have minimum resistance $1\ \text{k}\Omega$ $_{A}$✓ • have maximum resistance $11\ \text{k}\Omega$ $_{B}$✓ • be a (fixed) resistor (or resistors) **in series** with a variable resistor $_{C}$✓ **one** $1\ \text{k}\Omega$ resistor **in series** with **one** $10\ \text{k}\Omega$ **variable** resistor or valid labelled sketch $_{3}$✓ eg  	allow $_{A}$✓$_{B}$✓ for a switched 2 fixed resistor circuit that can produce both limiting values, eg   allow $_{A}$✓$_{B}$✓ (R_2) from $1\ \text{k}\Omega$ to $11\ \text{k}\Omega$; allow $_{AB}$✓ for deducing range = $10\ \text{k}\Omega$; for $_{C}$✓ allow any arrangement that allows R_2 to be varied **continuously** between limiting values; do not allow fixed resistor in parallel with a variable resistor for $_{3}$✓ CAO	3	1 × AO1 2 × AO3
Total			**12**	

Question	Answers	Additional comments/Guidance	Mark	AO
03.1		for $_1$✓ and $_2$✓ allow ≥ 4 sf rounding to 3 sf in range	3	2 × AO2 1 × AO1
	α in range with correct POT $_1$✓$_2$✓	for $_1$✓ α in range 4.45 to 4.57		
	α in range with incorrect OR missing POT $_1$✓	for $_1$✓ $_2$✓ α in range 4.45 to 4.57×10^{-3} allow $_{12}$✓ for α in range 4.39 to 4.63×10^{-3} OR allow $_{12}$✓ for 2 sf $\alpha = 4.5 \times 10^{-3}$		
	K^{-1} $_3$✓	for $_3$✓ condone $°K^{-1}$ OR $\frac{1}{K}$ OR $\frac{1}{{}^{o}K}$ do **not** accept $(°)C^{-1}$ do **not** accept k for K		

Question	Answers	Additional comments/Guidance	Mark	AO
03.2		allow valid work in 'wrong' answer space	2	AO1
	determines P using $V \times I$ in some form OR determines R using $\frac{V}{I}$ in some form $_1$✓	for $_1$✓ AND / OR $_2$✓ accept formulae in symbols or in words eg 'power = current × voltage'; accept 'voltmeter reading' for V / 'ammeter reading' for I; treat as neutral the idea of plotting an IV graph to find P and / or to find R		
	determines P using $V \times I$ AND R using $\frac{V}{I}$ in some form AND determines T using (their) R $_1$✓$_2$✓	for $_2$✓ allow 'use the equation with R'; any rearranged equation must be correct eg $T = \frac{R - R_0}{\alpha R_0} + T_0$; treat the following as neutral: (unqualified) 'use the equation' / 'use $T \propto R$ to determine T' / 'use (extrapolate) **Figure 6**' / 'use **Figure 8**'		

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr>
<td>03.3</td>
<td>2nd row of Table 2 P correct
AND
4th row of Table 2 P_2 correct $_1$✓

3rd row of Table 2:
P correct $\pm$ 0.2
AND
P_2 correct $\pm$ 0.2 $_2$✓

their P_1 = their P – their P_2
AND
all the data added to Table 2 is to 1 dp $_3$✓

<table>
<tr><th>T / K</th><th>P / W</th><th>P_1 / W</th><th>P_2 / W</th></tr>
<tr><td>960</td><td>3.7</td><td>1.2</td><td>2.5</td></tr>
<tr><td>1100</td><td>5.0</td><td>2.0</td><td>3.0</td></tr>
<tr><td>1370</td><td>8.8</td><td>4.8</td><td>4.0</td></tr>
<tr><td>1680</td><td>16.2</td><td>11.0</td><td>5.2</td></tr>
</table>
</td>
<td>only penalise dp in $_3$✓
for $_1$✓ (2nd row) $P = 5.0$ (W)
AND
(4th row) $P_2 = 5.2$ (W)

for $_2$✓ (3rd row) $P = 8.6$ to 9.0 (W)
AND
$P_2 = 3.8$ to 4.2 (W)

for $_3$✓ expect $P_1 = 4.4$ to 5.2 (W)</td>
<td>3</td>
<td>2 × AO2

1 × AO3</td>
</tr>
</table>

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr><td>03.4</td><td>intention to use a logarithmic plot to test power law:

suitable headings in Table 3
OR
suitable graph axis labels in Figure 9 $_1$✓

their P_1 data in Table 2 transferred to 3rd row / their P_1 used to complete 3rd row
AND
4 sets of $\log T$ and $\log P_1$ recorded in columns 3 and 4 of Table 3 $_2$✓

<table>
<tr><th>T / K</th><th>P_1 / W</th><th>log (T / K)</th><th>log (P_1 / W)</th></tr>
<tr><td>960</td><td>1.2</td><td>2.98</td><td>0.08</td></tr>
<tr><td>1100</td><td>2.0</td><td>3.04</td><td>0.30</td></tr>
<tr><td>1370</td><td>4.8</td><td>3.14</td><td>0.68</td></tr>
<tr><td>1680</td><td>11.0</td><td>3.23</td><td>1.04</td></tr>
</table></td><td>award $_1$✓ for use of bracket, solidus AND unit eg $\log (T / \mathrm{K})$ AND $\log (P_1 / \mathrm{W})$;
can be shown EITHER in the Table 3 headings OR for the Figure 9 axis labels;
accept $\lg (T / \mathrm{K})$ / $\log (T / \mathrm{k})$ for $\log (T / \mathrm{K})$;
accept columns interchanged / axes reversed

for $_2$✓ check that the $\log T$ AND $\log P_1$ values are correct to at least 2 dp;
all $\log T$ values to the same (minimum 2) dp;
all $\log P_1$ values to same (minimum 2) dp OR all to same (minimum 3) sf
ECF wrong P_1;
allow 4 sets of $\ln (T / \mathrm{K})$ and $\ln (P_1 / \mathrm{W})$

<table>
<tr><th>T / K</th><th>P_1 / W</th><th>ln (T / K)</th><th>ln (P_1 / W)</th></tr>
<tr><td>960</td><td>1.2</td><td>6.87</td><td>0.18</td></tr>
<tr><td>1100</td><td>2.0</td><td>7.00</td><td>0.69</td></tr>
<tr><td>1370</td><td>4.8</td><td>7.22</td><td>1.57</td></tr>
<tr><td>1680</td><td>11.0</td><td>7.43</td><td>2.40</td></tr>
</table></td><td>MAX 5</td><td>2 × AO1
2 × AO2
1 × AO3</td></tr>
</table>

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4 (cont)	**Figure 9 and processing**: suitable scales for their data; each axis labelled with (at least) their plotted quantity; allow interchanged axes $_3$✓	for $_3$✓ each scale must • accommodate all **their** data • have at least 4 evenly-spaced values marked along each axis • be linear, avoiding 'difficult' intervals • allow points to cover ≥ half the grid in both directions (expect use of a false origin) condone a suitably scaled and labelled **non-logarithmic** plot including P_1 against T		
	4 points plotted and a **ruled** line that is **continuous** (at least) from 1st point to 4th point $_4$✓	for $_4$✓ the 1st, 2nd and 4th points should lie on a straight line (by eye); check possible errant point(s) but allow minor plotting errors (≤ 2 minor squares); do **not** allow blobs, thick or faint points; allow a ruled line that is not the best line but do **not** allow a thick / faint / discontinuous line		
	an unrounded gradient result in the range 3.6 to 4.4 OR a gradient result correctly rounded to the nearest integer $_5$✓	for $_5$✓ do not penalise small steps; condone **one** read off error for reversed axes unrounded gradient range is 0.23 to 0.28 or inverse of gradient rounded		
	$n = 4$ CAO $_6$✓	$_6$✓ is contingent on $_5$✓		
	if the plot is log-log or ln-ln award $_{12}$✗$_3$✓$_{456}$✗ = 1 MAX if plot is T^4 against P_1 allow up to $_1$✓$_2$✓$_3$✓$_4$✗$_5$✗$_6$✗ = 3 MAX			

Question	Answers	Additional comments/Guidelines	Mark	AO

03.4 (cont)

Figure 9 with $\log (P_1 / \text{W})$ against $\log (T / \text{K})$

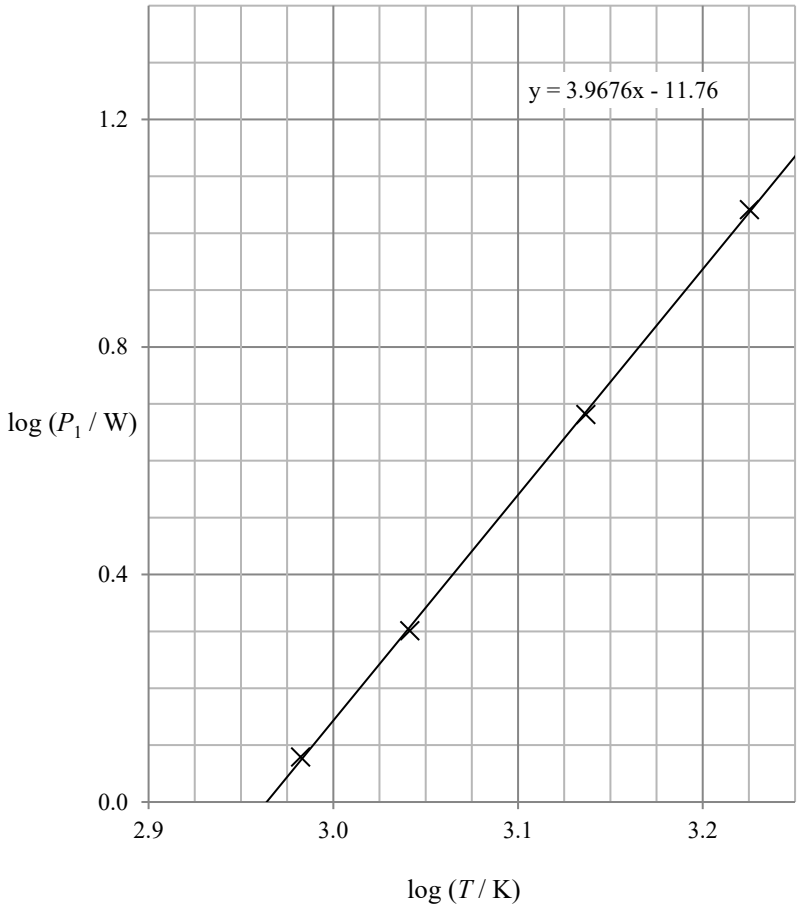
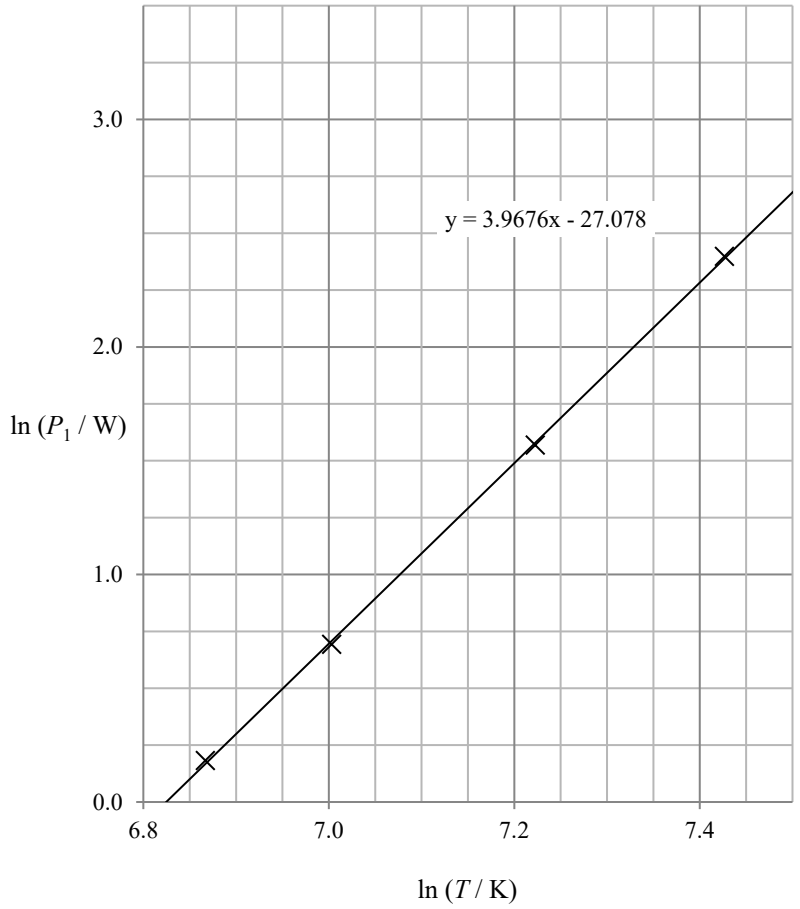


Figure 9 with $\ln (P_1 / \text{W})$ against $\ln (T / \text{K})$



	typical graphs using the14 cm × 14 cm grid on **Figure 9**: grid lines shown are at the semi-major (1 cm) intervals note the false origin is required for a suitable $\log T$ scale for these scales a minimum of 4 evenly-spaced values on each axis are expected for 3✓

Total			**13**

Question	Answers	Additional comments/Guidance	Mark	AO
04.1	working to determine t: EITHER $\frac{24.73 - 9.26}{n}$ where n is their number of turns between **P** and **Q** OR $\frac{x - 9.26}{13}$ where x is their vernier reading from **Figure 11** $_1$✓ $t = 1.19$ (mm) $_2$✓	for $_1$✓ n must be an integer AND x must be 2 dp; allow $\frac{15.47}{n}$ for $_2$✓ must see some correct working; accept >3 sf that rounds to 1.19	2	AO3

Question	Answers	Additional comments/Guidance	Mark	AO
04.2	MAX $_1$✓$_2$✓ from • diameter = $18(.0)$ + $(2\times)$ their t from **04.1** $_A$✓ • circumference = $\pi\times$ their diameter $_B$✓ • length = their circumference $\times$ their n from **04.1** $_C$✓ **correctly** calculates L using their $n\times\pi\times(18+$ their $t)$ OR using their $n\times\pi\times(18+(2\times$ their $t))$ $_3$✓	for $_A$✓ accept $t = 1.2\ (\text{mm})$ for $_B$✓ allow $(18+t)$ OR $(18+2t)$ for their diameter; condone $(18+\frac{t}{2})$ OR 18 the award of $_3$✓ is contingent on the award of $_A$✓ $_B$✓ and $_C$✓ for $_3$✓ L must be given to 3 sf ie a **whole number** of millimetres condone the award of $_1$✓$_2$✓$_3$✓ if working is missing but recognisable values of n and t are seen	3	AO3

Question	Answers	Additional comments/Guidance	Mark	AO
04.3	identifies **B** $_1$✓	for $_1$✓ must reject **A** and **D**; allow **C only** if an additional mark added **to the tube** at this height when the tube is **at the equilibrium position** OWTTE	2	AO1
	where (the top of the test tube) is moving fastest / has maximum kinetic energy / where the transit time is least $_2$✓	$_2$✓ is contingent on $_1$✓ for $_2$✓ comments about the equilibrium position / equilibrium point / centre of oscillation / rest position are neutral; the idea that 'the (top of the) test tube will always pass point' is neutral; explaining why **A**, **C** and **D** are not suitable is neutral		

Question	Answers	Additional comments/Guidance	Mark	AO
04.4		award $_1$✓ and $_2$✓ independently	2	1 × AO1
	derives an expression that can be used to determine ρ for milk OR evaluates $T^2\rho$ OR $T\sqrt{\rho}$ (for oil) $_1$✓	for $_1$✓ accept a valid expression, any subject, without full substitution, eg $\rho_{\text{milk}} = \rho_{\text{oil}} \dfrac{T_{\text{oil}}^2}{T_{\text{milk}}^2}$ OR $0.587^2 \times 849$ seen / 293 seen OR $0.587 \times \sqrt{849}$ seen / 17.1 seen		1 × AO2
	density of liquid $= \left(849 \times \dfrac{0.587^2}{0.534^2}\right) = 1.03 \times 10^3$ (kg m^{-3}) $_2$✓	for $_2$✓ 3 sf only but condone 4 sf answer in the range 1025 to 1030 only		

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr><td>04.5</td><td>MAX 3 from
a valid modification $_1$✓
a rationale for the modification $_2$✓
an additional valid modification $_3$✓
a rationale for the second modification $_4$✓</td><td>
<table>
<tr><td>$_1$✓ (idea of) increasing the depth of the oil,
eg add (more) oil to the beaker
do not accept ‘use a narrower beaker’ as this increases drag</td><td>$_2$✓ (idea of) increasing the (initial) displacement / amplitude / height of the test tube
OR
increasing the (initial) energy of the system
allow ‘to produce larger / bigger oscillations’</td></tr>
<tr><td>$_3$✓ (idea of) increasing the distance between the test tube and the beaker walls,
eg use a wider / larger diameter beaker AND add oil to (at least) the original depth (to maintain the initial amplitude)</td><td>$_4$✓ (idea of) reducing the drag / (fluid) resistance / (fluid) friction / velocity gradient;
condone (idea of) ‘reducing the damping)</td></tr>
</table>
for $_1$✓ ‘use a taller / deeper / larger beaker’ is neutral;
for $_2$✓ (idea of) ‘obtain greater oscillations’ is neutral;
for $_3$✓treat as neutral any changes to the test tube, wire or oil;
condone ‘water’ / ‘liquid’ for oil
for $_4$✓ ‘reduce the effect of damping’ is neutral</td><td>3</td><td>AO3</td></tr>
<tr><td>Total</td><td></td><td></td><td>12</td><td></td></tr>
</table>