A-level
PHYSICS
7408/3A

Paper 3 Section A

Mark scheme

June 2021

Version: 1.1 Final

2 1 6 A 7 4 0 8 / 3 A / M S

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.

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 not 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.

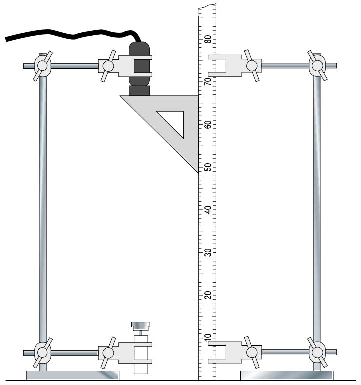
When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use 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 mark

Question	Answers	Additional comments/Guidelines	Mark	AO
01.1	finds d by reading position of (lower end of) detector; subtracts 138 mm or wtte $_1$✓ annotates **Figure 1** to show suitable use of a recognisable set-square $_2$✓	for $_1$✓ allow 'reads / measures height of detector' / 'distance from detector to bench'; reject 'measures height of clamp **T**' if 'subtracts 138' is not seen; allow 'subtract distance from source to bench' / 'between source and bench' / 'height of source from ground' / 'position of top / open end / mouth of source'; allow 'measures height of the detector and the source and finds difference'; condone 'reversed' subtraction for $_2$✓ expect a <u>triangular</u> 90° set-square in contact with a vertical edge of the ruler, top edge aligned with open end of the detector, eg 	2	AO2-1g

		condone use of recognisable T-square in contact with vertical edge etc		

Question	Answers	Additional comments/Guidelines	Mark	AO
01.2	background count rate correct $_1$✓	for $_1$✓ accept any of: background count rate = 0.7(0) / $\frac{630}{900}$ (s^{-1}) OR background count in 100 s = 70 OR background count in 300 s = 210	1	AO1-1b
	working leading to correct R_C $_2$✓	for $_2$✓ [cao] ≥ 2 sf R_C = 0.33 (s^{-1}) reject R_C = 0.30 if their uncorrected count has been rounded to 1.0	1	AO2-1h

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr>
<td>01.3</td>
<td>
attempts two calculations that would lead to a conclusion ₁✓

a reasoned judgement that the evidence does not support the prediction ₂✓

<table>
<tr><td>d / mm</td><td>380</td><td>530</td><td rowspan="2">Δ%</td></tr>
<tr><td>R_C / s^{-1}</td><td>0.76</td><td>0.33</td></tr>
<tr><td>$d^2 \times R_C$</td><td>$1.1(0) \times 10^5$</td><td>9.27×10^4</td><td>18%</td></tr>
<tr><td>$d \times \sqrt{R_C}$</td><td>331 / 330</td><td>305 / 310</td><td>8.4%</td></tr>
</table>
<table>
<tr><td>d / mm</td><td>380</td><td>530</td><td rowspan="2">Δ%</td></tr>
<tr><td>R_C / s^{-1}</td><td>0.76</td><td>0.3 (1 sf)</td></tr>
<tr><td>$d^2 \times R_C$</td><td>$1.1(0) \times 10^5$</td><td>$8(.43) \times 10^4$</td><td>29%</td></tr>
<tr><td>$d \times \sqrt{R_C}$</td><td>331 / 330</td><td>$3.(0) \times 10^2$</td><td>14%</td></tr>
</table>
</td>
<td>
for ₁✓ the result of at least one calculation of $d^2 \times R_C$ or of $d \times \sqrt{R_C}$ must be correct to 2 sf (see table) otherwise withhold both marks;

allow use of d in m but reject POT error;

allow 1 sf $d^2 \times R_C$ for use of $R_C = 0.3$;

allow 530^2 × their 01.2 result

for ₂✓ two correct calculations of $d^2 \times R_C$ or of $d \times \sqrt{R_C}$, both must be correct to 2 sf

OR

one correct calculation of $d^2 \times R_C$ or of $d \times \sqrt{R_C}$ correct to 2 sf and an appropriate reverse-working calculation;

the statement rejecting the prediction should be supported by a calculation of the percentage difference between the results of their calculations (see Δ% in table);

condone weaker ‘large’ / ‘significant differences’ (between calculation results);

reject ‘prediction not correct’ because ‘values are different’ / ‘not constant’ / ‘not close enough’
</td>
<td>2</td>
<td>AO3-1a</td>
</tr>
</table>

Question	Answers	Additional comments/Guidelines	Mark	AO
01.4	lower / adjust the position of the detector / clamp **T** $_1$✓	for $_1$✓condone 'lower clamp' (this implies clamp **T** since **B** cannot be lowered further) allow 'remove source using tongs while adjusting detector / clamp **T**' otherwise $_2$✗	1	AO3-1b
	to maximise distance between the experimenter and the source or wtte OR to reduce (limit) exposure (time) of the experimenter to radiation or wtte $_2$✓	for $_2$✓ allow 'not going (too) close (to source)' reject 'don't touch / make contact with source' suggesting using lead shielding is neutral allow $_{12}$✓ for 'remove source or wtte using tongs to maximise distance etc before moving **B** upwards' changes to the position of source / clamp **B** without the use of tongs loses both marks	1	AO1-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
01.5	determines $10^a - 10^b$ where a and b are (any) plotted values of log (d / mm) $_1$✓ use of $\Delta d = \frac{10^a - 10^b}{n}$ where n is 1, 2, 3 or 4; Δd in range 47(.0) to 53(.0) (mm) $_2$✓	insist on a and $b \geq 2$ dp; allow read-off errors ± one square; expect $\frac{10^{2.52} - 10^{2.11}}{4}$ = 50(.6) (mm); allow $_{12}$✓for $\frac{e^a - e^b}{n}$ leading to Δd correct for their values $_2$✓is contingent on $_1$✓ie there is no credit for an unsupported answer	2	AO3-1a

Question	Answers	Additional comments/Guidelines	Mark	AO
01.6	suitable analysis $_1$✓ appropriate use of **Figure 2** $_2$✓ processing and conclusion $_3$✓	for $_1$✓ log $R_C = -2$ log d + log k seen; minus sign essential for $_2$✓ draw best-fit line **and** measure gradient; allow implication that a (linear) best-fit line is drawn and the gradient is being measured, eg 'check gradient of best-fit line'; condone m = gradient for $_3$✓ states that the prediction is confirmed if the gradient / m is ≈ -2 OR prediction is **not** confirmed if the gradient is $\neq -2$ condone 'the gradient should be -2 (to confirm prediction)'I (**no** ECF for $m = (+)2$ if denied in $_1$✓ for missing – sign) allow $_{123}$✓ prediction is **not** confirmed if the best-fit line is a curve reject 'prediction is confirmed if the best-fit line is straight' / 'there is a negative gradient' / 'because 'k is constant'	3	AO3-2a

Question	Answers	Additional comments/Guidelines	Mark	AO
01.7	$t_d = 1.96 \times 10^{-4}$ (s) ✓	minimum 2 sf; accept 196 μs; calculation should be $\frac{102-100}{102 \times 100}$ so only accept 2.0×10^{-4} (s) / 200 μs only if **rounding up** ($\frac{100-98}{100 \times 98}$ gives $t_d = 2.04 \times 10^{-4}$ (s))	1	AO2-1h

Question	Answers	Additional comments/Guidelines	Mark	AO
01.8	random nature of decay or wtte $_1$✓ idea that more than one photon may arrive per 0.01 s interval OR idea that no photon may arrive during per 0.01 s interval OR photons 'arrive randomly' / 'do not arrive at a steady rate or wtte $_2$✓	for $_1$✓ condone 'the source emits (photons) sporadically' / 'unpredictably'; reject explanation based on exponential decay reject 'decay occurs by chance' / 'source does not emit photons at a constant rate' / 'photons decay' / 'decay is spontaneous / inconsistent' $_2$✓ is contingent on $_1$✓ (if no other answer given) allow $_{12}$✓ for: 'only counts 50 since detector still 'dead' at 0.01 s so only 'sees' odd-numbered photons'; use of formula to show $R_1 = 50$ is neutral	1 1	AO1-1a AO1-1b

Total			16

Question	Answers	Additional comments/Guidelines	Mark	AO
02.1	reads off λ_p 1✓	for 1✓ condone POT; expect $\lambda_p = 635 \pm 2$ (nm) / $635 \pm 0.02 \times 10^{-9}$ / $6.35 \pm 0.02 \times 10^{-7}$ (m) allow evidence of working on **Figure 3**	1	AO1-1a
	use of $n \times$ their $\lambda_p = d \sin \theta$ 2✓	for 2✓ accept subject N with no / incomplete substitution, eg $N = \frac{\sin \theta}{n \times \lambda_p}$ OR subject d and <u>full</u> substitution, eg $d = \frac{5 \times \text{their } \lambda_p}{\sin 76.3}$ / $5.15 \times$ their λ_p OR correct result $d = 3.27$ ($\times 10^{-6}$ (m)); allow ECF in λ_p including POT; allow recognisable d / 2 sf intermediate result	1	AO2-1h
	$N = \left(= \frac{1}{d} = \frac{1}{3.27 \times 10^{-6}} \right) = 3.06 \times 10^5$ 3✓	for 3✓ accept ≥ 3 sf in range 3.05 to 3.07 × 10^5 OR	1	AO3-1b

		$N = \frac{0.194}{\text{their } \lambda_p}$ (allow ECF for λ_p out of range but not if due to POT)		

Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	identifies an appropriate physical characteristic that makes the measurement of the (5th) maximum more difficult ✓	take 'it' to be the 5th maximum / peak (see rubric marking point 3.3) (centre difficult to locate because) (5th) 'maximum is wider' / 'peak less pronounced' / 'less defined' or wtte; allow 'maximum more spread out' / 'less pronounced' OR maximum 'is fainter' / 'less bright' / 'intensity reduced'; reject 'not as clear' OR (cannot use edges to determine location of centre because) 'whole maximum (may be) not visible' / 'can't see edges' OR (**L**$_R$ produces a range of wavelengths so) 4th and 5th / adjacent fringes may overlap	1	AO1-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	extrapolation of linear region of the **L_R** characteristic $_1$✓ V_A for **L_R** in range 1.91 to 1.93 (V) $_2$✓	for $_1$✓ reads off where a ruled extrapolation to the linear region of the **L_R** characteristic reaches the horizontal axis the line must be free from discontinuities; condone a ruled dashed line condone tangent meeting curve at $I \geq 10$ mA for $_2$✓ > 3 sf acceptable if rounding to 3 sf	2	AO1-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
02.4	any fully correct calculation of the Planck constant $_1$✓	for $_1$✓ allow 2 sf use of $c = 3(.00) \times 10^{8}$ AND $e = 1.6(0) \times 10^{-19}$ AND EITHER V_A from **02.3** AND λ_p in range 620 to 650 nm / ECF their λ_p from **02.1** OR V_A = 2.00 AND λ_p in range 550 to 580 nm;	1	AO3-1b

	~~calculates mean of two valid calculations of the Planck~~ constant; result in range 6.10 to 6.50 × 10^{-34} (J s) $_2$✓	for $_2$✓ Planck constant result rounding to correct 3 sf (check very carefully working leading to data booklet value 6.63 × 10^{-34})	1	AO1-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
02.5	V_F corresponding to I_F = 21 mA read from **L** graph in **Figure 4**; calculates R from $\frac{6.1 - \text{their } V_F}{21(.0 \times 10^{-3})}$ $_1$✓	use of V_F = 2.01 (V) leading to R = 195 (Ω) earns both marks for $_1$✓ accept evidence of working on **Figure 4** condone 2 sf eg V_F = 2.0 (V) allow POT error for I_F	1	AO1-1b
	R = 195 (Ω) from $\frac{6.10 - 2.01}{21(.0) \times 10^{-3}} = 195$ $_2$✓	for $_2$✓ evidence to show use of V_F = 2.01 ± 0.01 (V) must be seen, ie allow $\frac{6.10 - 2.00}{21(.0) \times 10^{-3}} = 195$ OR $\frac{6.10 - 2.02}{21(.0) \times 10^{-3}} = 194$	1	AO2-1d

Total			**10**	

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	tick in **first** box (2.7 V) ✓	[cao]	1	AO2-1d

Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	move position until needle / pointer hides / is aligned with its reflection in the mirror or wtte $_1$✓ this reduces / eliminates <u>parallax</u> error OR to ensure scale is read from directly above $_2$✓	for $_1$✓ allow 'view scale so needle / pointer hides reflection'; condone 'there is no reflection' for $_2$✓ reject 'reduces / eliminates human error' allow 'reading is made when at right angles' / 'perpendicular to the scale'; reject 'view scale at eye level' / 'so not looking at an angle' / 'so ~~not~~ looking straight at needle'	2	AO1-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	average $T_{1/2}$ correct OR uncertainty in $T_{1/2}$ correct ₁✓	for ₁✓ average $T_{1/2}$ $= 12.04$ (s); reject 12.0 allow credit for correct $T_{1/2}$ seen in working for percentage uncertainty; uncertainty in $T_{1/2}$ (from half range) $= 0.11$ (s)	1	AO2-1h
	percentage uncertainty in $T_{1/2}$ correct ₂✓	for ₂✓ minimum 2 sf; correct answer rounds to $0.91(4)\%$	1	AO1-1b

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	time constant = $\dfrac{\text{their mean } T_{1/2}}{\ln 2}$ OR $\dfrac{-(\text{their mean } T_{1/2})}{\ln 0.5}$ ✓	expect 17.37 (s); allow minimum 3 sf 17.4 / use of ln 2 = 0.69 for leading to 17.45; reject use of $T_{1/2}$ $= 12$ leading to 17.31; reject $\dfrac{\text{their mean } T_{1/2}}{\ln 0.5}$ (ignoring –sign in result)	1	AO2-1d

Question	Answers	Additional comments/Guidelines	Mark	AO
03.5	ways ensure pd across **C** doesn't exceed 3 V before connecting **C** to **X** $_1$✓ as **X** is connected $_2$✓	for $_1$✓ discharge **C** / connect flying lead to **Y** / 'reset to 0 V' (before reconnecting); reject 'reset equipment' for $_2$✓ reduce the <u>output pd</u> / socket **X** (or wtte) to ≤ 3 V (then reconnect **C** and adjust pd so meter reads full-scale); reject 'only charge **C** to 3 V' idea of adding resistance to limit pd is neutral	MAX 3	AO3-2b
	suggests timing for ΔV > 1.5 V or wtte $_{3a}$✓ OR take repeated readings (of $T_{½}$ or time constant); any valid processing eg calculate an average value / reject anomalies / check results are concordant or wtte $_{3b}$✓ check / correct / compensate for any <u>zero error</u> (on the voltmeter) $_4$✓	for $_{3a}$✓ accept 'increase timing interval' / time for concurrent half lives or wtte; reject 'measure time for **C** to fully discharge' for $_{3b}$✓ accept 'repeat the experiment and calculate a mean' only if this refers to $T_{½}$ reject 'repeat etc to get more reliable result' for $_4$✓ accept 'check etc for <u>systematic error</u>' 'student' is repeating previous experiment so reject idea of making V the dependent variable / plot V against t / using data logging		

	suggests a valid quantitative test of theory by comparison with the result obtained using the 15 V range 5✓	(theory will be correct if) half-life / time constant is one fifth / 20% (of previous value) / about 3.5 s / time constant reduced by 80% / ratio of time constant to range / ratio of half-life to range is same / similar reject 'plot ln V against t, find (–gradient^{-1})'	1	AO2-1d

Question	Answers	Additional comments/Guidelines	Mark	AO
03.6	in answer space 1: any valid comment about the values of V in **Table 2** 1✓ corresponding explanation 2✓ (contingent on 1✓) in answer space 2: different valid comment about the values of V in **Table 2** 3✓ corresponding explanation 4✓ (contingent on 3✓) only credit one comment and explanation per answer space comments about the number of data sets are neutral	give credit for any good physics, eg V recorded to nearest volt 1✓ because of (low) scale resolution / hard to interpolate between markings; reject 'values easier to plot' 2✓ different / decreasing intervals between values of V / more lower values of V 3✓ to make intervals between t readings about the same / or wtte; allow 'to distribute data on graph' or wtte / to allow (convenient interval for) t to be read / recorded 4✓ no readings for V < 2 V / smallest V = 2 V 5✓ because difficult to establish exact moment to read stopwatch / needle is moving too slowly / sensible comment about parallax 6✓ V data over wide range / from <u>14 to 2</u> (V) 7✓	4	AO2-1g

		to maximise evidence available (for graph / **Figure 8**) or wtte 8✓ no readings for V > 14 V / largest V = 14 V 9✓ can begin discharge **C** before starting stopwatch 10✓		

Question	Answers	Additional comments/Guidelines	Mark	AO
03.7	attempts gradient calculation using $\Delta \ln(V / \mathrm{V})$ divided by Δt; use of $\lvert \text{gradient} \rvert = \left\lvert \frac{-1}{R \times C} \right\rvert$ 1a✓ OR reads off ln V_0, ln V and corresponding Δt from **Figure 8**; use of $V = V_0 e^{-\frac{t}{RC}}$ 1b✓	for 1a✓ expected gradient is –0.077; condone one read-off error in gradient calculation or missing sign; allow any subject / (at least) substitution of their gradient into a valid calculation for R condone missing / wrong POT for capacitance for 1b✓ condone one read off error; allow any subject / (at least) substitution of all their data into a valid calculation for R condone missing / wrong POT for capacitance 1b✓variation below: reads off ln V_0 and finds V_0 = 14.1 (V); $V = 0.37V_0$ when $t = RC$ $\therefore V = 0.37V_0 = 5.2\ \mathrm{V}$	1	AO2-1h

	valid working leading to voltmeter resistance ≥ 3 sf in range 15.0 kΩ to 16.6 kΩ $_2$✓ voltmeter resistance ≥ 3 sf in range 15.5 kΩ to 16.1 kΩ $_3$✓	reads of ln $5.2 = 1.65$; $\Delta t \approx 13$ (s) $\therefore R = \frac{13}{C}$ accept > 3 sf that rounds to 3 sf in range allow $_{23}$✓ = 1 MAX for POT error allow $_{123}$✓ = 1 MAX for using **Table 2** data	2	AO3-a1a

Question	Answers	Additional comments/Guidelines	Mark	AO
03.8	reads ln(V_{10} / V) from **Figure 8**; deduces V_{10} in range 6.36 to 6.69 (V) $_1$✓	for $_1$✓ V_{10} to ≥ 3 sf required; accept > 3 sf that rounds to 3 sf in range; accept V_0 from ln V_0 read off and V_{10} deduced from $V_{10} = V_0 e^{\frac{-10}{CR}}$; condone use of $V_0 = 15$(V); if V_{10} is not recorded allow $_1$✓ for use of $e^{\ln V_{10}}$ in the calculation of I_{10} where ln(V_{10} / V) is in the range 1.85 to 1.90	1	AO1-1b
	≥ 2 sf result in range 3.9 to 4.3×10^{-4} (A) $_2$✓	for $_2$✓ allow use of resistance = 16×10^3 (Ω); accept ≥ 3 sf result that rounds to 2 sf in range	1	AO2-1g

		allow ECF if V_{10} is **correctly obtained** from an incorrect ln(V_{10} / V) read off and I_{10} calculated using $\frac{\text{their } V_{10}}{\text{their voltmeter resistance}}$		

Total			**19**