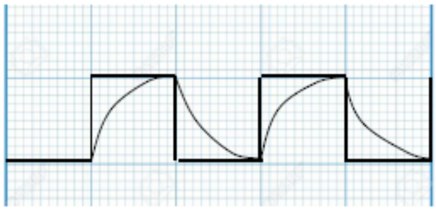
Mark Scheme

Q1.

Question Number	Acceptable answers		Additional guidance	Mark
	• Time axis: one cycle = 50 OR two cycles =100 • Use of time constant = *RC* • Charging curve, from 25 ms to 50 ms, just about reaching 5V as shown (ecf from their T) • One corresponding discharge curve • Curve should look exponential	(1) (1) (1) (1) (1)	<u>Example of calculation</u> $T = 1/f = 1/20\ Hz = 0.050\ s$ $Two\ cycles = 2 \times 0.050\ s = 0.10\ s = 100\ ms$ $Time\ Constant = 100 \times 50 \times 10^{-6} = 0.005\ s$ In half a cycle (0.025 s) there are 0.025 s / 0.005 s = 5 Time constants Ignore anything drawn in the first half cycle  Time period should be marked 50 ms or equivalent	5

[9]

Q2.

(a) Capacitor must not lose charge through the meter ✓

1

(b) Position on scale can be marked / easier to read quickly etc ✓

1

(c) Initial current = $\frac{6}{100000}$ = 60.0 μA ✓

100 μA or 200 μA ✓ (250 probably gives too low a reading)

Give max 1 mark if 65 μA (from 2.6) used and 100 μA meter chosen

2

(d) 0.05 V ✓

1

(e) Total charge = 6.0 x 680 x 10^{-6} (C) (= 4.08 mC) ✓

Time = 4.08 x 10^{-3} / 60.0 x 10^{-6} = 68 s ✓

Hence 6 readings ✓

3

(f) Recognition that total charge = 65 t μC and final pd = 0.098 t

so C = 65μ / 0.098✓

660 μF ✓

Allow 663 μF

2

(g) (yes) because it could lie within 646 – 714 to be in tolerance ✓

OR

it is 97.5 % of quoted value which is within 5% ✓

1

(h) Suitable circuit drawn ✓

Charge C then discharge through R and record V or I at 5 or 10 s intervals ✓

Plot ln V or ln I versus time ✓

gradient is 1 / RC ✓

OR

Suitable circuit drawn ✓

Charge C then discharge through R and record V or I at 5 or 10 s intervals✓

Q3.

planning

(a) sensible key factor e.g. p.d. across paper, that, when varied, leads to the determination of resistance: candidate then goes on to estimate the thickness of the paint layer on strip [only allow direct measurement of resistance if the investigation is of how either width or length of a rectangular strip affects the resistance of the paper] **(1)**

(b) correct measuring instrument given [allow circuit diagram] **(1)**

(c) dimensions of paper constant when resistance measured [to see how a certain dimension influences the resistance, width (if length varied)/length (if width varied)] **(1)**

(d) check that current through paper does not exceed 200 mA **(1)**

(e) sensible qualitative prediction given: thickness can only be estimated due to uncertainty in resistivity **(1)**

(f) thickness of layer (assuming uniform coating) in range 10^{-7} to 10^{-11} m **(1)**

[or (e) sensible qualitative prediction given: $R \propto l$ or $R \propto w^{-1}$]

(g) reasonable physics reasoning given in support: similarity with behaviour of a metallic conductor **(1)**

(h) use of V/I to find R [use of repeated readings to reduce uncertainty in measurement of dimension] **(1)**

(i) calculating possible range of thickness using limiting values of resistivity /

Q3.

(a) peak (to peak) voltage = 6.3(0) (V) ✓

accept any answer that rounds to 6.3 V

do not allow power of ten errors, eg 0.0063 V

1

(b) period = 8 divisions

(= 8 × 0.5 × 10^{-3} (s))

= 4 ms $_1$ ✓

$$\left(f = \frac{1}{T} = \frac{1}{0.004}\right)$$

= 250 (Hz) $_2$ ✓

award both marks if 250 Hz seen

accept 4.0(0) ms for $_1$ ✓ but reject 4.05, 3.95 etc

ecf$_2$ ✓ for wrong period

2

(c) any valid approach leading to *RC* in range

2.1 ×10^{-4} to 3.4 ×10^{-4} or 3 ×10^{-4} (s)

OR

their *T* in 02.2 × 0.069 ± 10 % 12 ✓ ✓

1 mark can be awarded for use of any valid approach in which *RC* is seen with substitutions or with rearranged equations, eg

$0.5 = 6.3e^{\frac{-6\times10^{-3}}{RC}}$ or $RC = \dfrac{-t}{\ln\left(\dfrac{V}{V_0}\right)}$ or

$RC = \dfrac{t}{\ln\left(\dfrac{V_0}{V}\right)}$

OR

$1.75 \times 10^{-4} = RC \times \ln 2$

OR

$RC = \dfrac{t_{0.5}}{\ln(2)}$

valid approaches;

reads off t when C starts to discharge and t at a lower value of V:

rearranges $V = V_0 e^{\frac{-\Delta t}{RC}}$ *to calculate RC*

for ecf 2 ✓ *Δt used must correspond to interpretation of time base used in determining the frequency in (b); there is no ecf for misinterpretation of the voltage scale*

OR

reads off t when C starts to charge and t at a higher value of V:

rearranges $V = V_0\left(1 - e^{\frac{-\Delta t}{RC}}\right)$ *to calculate RC etc*

OR

determines half-life $t_{0.5}$ *and finds RC from* $\dfrac{t_{0.5}}{\ln(2)}$

for ecf 2 ✓ $t_{0.5}$ *used must correspond to etc*

OR

uses idea that during discharge V falls to $0.37V_0$ *in one time constant: determines suitable V and reads off RC directly*

for ecf 2 ✓ *time interval used must correspond to etc*

OR

uses idea that during charging V rises to $0.63V_0$ *in one time constant: determines suitable V and reads off RC directly*

reject idea that V falls to zero in 5RC

(d) qualitative comment

idea that the waveform will stretch horizontally ₁ ✓

quantitative comment

by a factor of $\left(\frac{0.5}{0.2} = \right) 2.5$ ₂ ✓

OR

half a cycle now covers 10 (horizontal) divisions on the screen ₂ ✓ (and also earns ₁ ✓)

(so the) resolution of the time axis has increased ₃ ✓ (and also earns ₁ ✓)

measuring larger distance / across more divisions from the screen reduces (percentage) uncertainty in reading the time (constant / interval / half life) ₄ ✓

for ₁ ✓ look for reference to time axis or direction waveform is re-scaled

accept 'graph is longer/stretched' or 'will not see whole cycle' or 'fewer cycles shown' or 'period takes more space' or 'distance being measured is larger' or 'time per division is less' or 'larger in x direction' or 'time is stretched'

reject 'waveform becomes larger' or 'may not see whole cycle' or 'measuring larger time'

for ₂ ✓ there needs to be valid quantitative detail

award ₁₂ ✓✓ for 'half a cycle now fills the screen' or 'half a cycle is displayed' as these clearly recognise the stretching is along the time axis and 'half' is quantitative

accept 'new distance (on screen corresponding to half life or time constant) is 2.5 × answer shown in working for (c)'

the candidate who realises that half a wave now covers the complete width of the screen cannot claim this is a disadvantage; they would still be able to bring either half cycle into view by using the X-shift and find RC for ₃ ✓ uses technical language correctly

ignore (but do not penalise) 'times are more precise' or 'more accurate'

reject 'smaller resolution' or 'lower resolution'

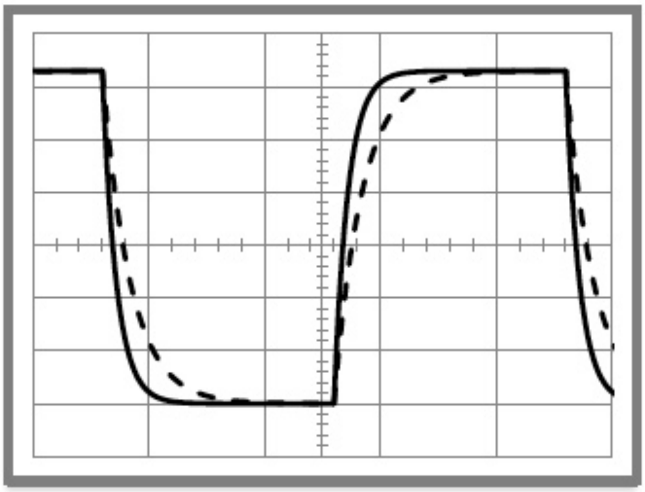
for 4 ✓ there needs to be a qualifying explanation for the comment about uncertainty

reject 'advantage because the (time) scale is easier to read'

3 MAX

(e) valid sketch on **Figure 7** showing discharge time to 0 V reduced and charging time to peak voltage reduced (see below) ₁ ✓

connecting resistor in parallel with R halves [reduces by 50%] circuit [total] resistance [time constant] 2 ✓



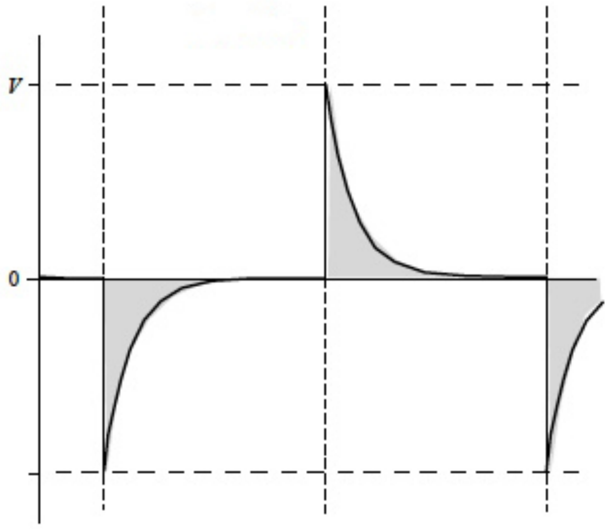
do not insist on seeing second discharge although if shown this must look correct

2

(f) amendment to **Figure 8** showing waveform across R with approximately the correct shape, amplitude ± *V* and the correct phase

correct waveform shown while signal generator output is low (0 V): only the complete negative half cycle needs to be shown but if second negative half cycle is included it must be correct 1 ✓

correct waveform shown while voltage across signal generator output is high; condone no signal or signal = 0 V before going to –V for the first time 2 ✓



don't insist on seeing vertical lines

2

(g) reduce the (sensitivity of) (Y-voltage)) gain 1 ✓

(change) to 2 V division^{-1} 2 ✓ (and earns 1 ✓)

adjust the Y (vertical) shift 3 ✓

'make (Y-) gain smaller' or 'increase the volts per division' or 'reduce the Y-resolution' are acceptable substitutes for 'reduce the (Y-)gain'

<u>increase</u> the (Y-) gain to 2 V division^{-1} $_2$ ✓not $_1$ ✓

<u>reduce</u> the (Y-) gain to 0.5 V division^{-1} $_1$ ✓not $_2$ ✓

ignore any comment about time base or 'X-gain'

if all positive waveform is given for (f) allow sensible comment about triggering/stability control, eg

waveform may not be stable $_1$ ✓; adjust triggering $_2$ ✓

2 MAX

[14]

(a)	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of the three levels according to the following criteria. **High Level (good to excellent) 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate provides a comprehensive and logical description of the sequence of releasing the ball and taking measurements of initial and final voltages. They should identify the correct distance measurement and show a good appreciation of how to use these measurements to calculate the time and acceleration from them. Time should be found from capacitor discharge, using known C and R values. Repeated readings would be expected in any answer worthy of full marks, but five marks may be awarded where repetition is omitted. **Intermediate Level (modest to adequate) 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate provides a comprehensive and logical description of the sequence of releasing the ball and taking measurements of the initial and final voltages. They are likely to show some appreciation of the use of suvat equations to calculate the acceleration, although they may not recognise the need to measure a distance. **Low Level (poor to limited) 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may only be partly appropriate. The candidate is likely to have recognised that initial and final voltages should be measured, but may not appreciate the need for any other measurement. They may present few details of how to calculate the acceleration from the voltage measurements. **The explanation expected in a competent answer should include a coherent selection of the following points.** **Measurements** • initial pd across C (V_0) from voltmeter (before releasing roller) • distance *s* along slope between plungers • final pd across C (V_1) from voltmeter • measurements repeated to provide a more reliable result **Analysis** • time *t* is found from $V_1 = V_0 e^{-t/RC}$, giving $t = RC \ln (V_0/V_1)$ • from $s = ut + ½ at^2$ with $u = 0$, acceleration $a = 2s/t^2$ • repeat and find average *a* from several results	**max 6**

(b)	(i)	$RC = 22 \times 10^{-6} \times 200 \times 10^{3}$ [or = 4.4 (s)] ✓ (4.40) $5.8 = 12.0\ e^{-t/4.40}$ ✓ gives $t = 4.40 \ln(12.0/5.8) = 3.2$ (3.20) (s) ✓	**3**
(b)	(ii)	$a\left(= \frac{2s}{t^2}\right) = \frac{2 \times 2.5}{3.20^2}$ ✓ = 0.49 (0.488) (m s^{-2}) ✓	**2**
		Total	**11**

Question	Answer	Marks
5	**Defining the problem**	
	R is the independent variable and *T* is the dependent variable, or vary *R* and measure *T*	**1**
	keep *C* constant	**1**
	Methods of data collection	
	labelled diagram or correct symbols of workable circuit including: • (d.c.) power supply correctly positioned • (neon) lamp correctly positioned do not accept ohmmeter in circuit	**1**
	circuit diagram to determine resistance of resistors e.g. using ammeter and voltmeter OR ohmmeter	**1**
	method to determine period or *T*, e.g. use a stopwatch / timer / oscilloscope do not accept counting the flashes in a specified time	**1**
	circuit diagram showing voltmeter(s) or oscilloscope(s) to determine V_i and V_F	**1**
	Method of Analysis	
	plots a graph of *T* against *R*	**1**
	$K = \frac{\text{gradient}}{C}$	**1**
	$V_L = V_i - (V_i - V_F)e^K = V_i - (V_i - V_F)e^{\frac{\text{gradient}}{C}}$	**1**

Question	Answer	Marks
5	**Additional detail including safety considerations**	**Max 6**
	switch off (high voltage) circuit (before changing the resistor) / wear insulating gloves to prevent electrocution / shock	**D1**
	resistance of resistors linked to diagram is V / I for ammeter / voltmeter method or gradient of appropriate graph or resistance from ohmmeter	**D2**
	input voltage or V_i is constant	**D3**
	repeat experiment for each value of R and average T	**D4**
	90 V (or larger) power supply do not accept a.c. or signal generator	**D5**
	for stopwatch method: time 10 or more flashes and divide by number of flashes for oscilloscope method: length of wave × timebase	**D6**
	record value of capacitance from the capacitor or method to determine capacitance	**D7**
	appropriate circuit to enable capacitance to be determined	**D8**
	relationship valid if a straight line passing through the origin is produced	**D9**
	method to obtain a measurable time period e.g. do a preliminary experiment to choose appropriate resistors, use large values of R or C	**D10**

Question	Answer	Marks
6(a)	gradient = $\frac{1}{YE}$ y-intercept = $\frac{1}{E}$	**1**
(b)	<table><tr><td>2.7 or 2.70</td><td>0.833 or 0.8333</td></tr><tr><td>1.4 or 1.35</td><td>0.513 or 0.5128</td></tr><tr><td>0.90 or 0.900</td><td>0.426 or 0.4255</td></tr><tr><td>0.68 or 0.675</td><td>0.364 or 0.3636</td></tr><tr><td>0.54 or 0.540</td><td>0.345 or 0.3448</td></tr><tr><td>0.45 or 0.450</td><td>0.328 or 0.3279</td></tr></table>	
	All first column correct. Allow a mixture of significant figures.	**1**
	All second column correct. Allow a mixture of significant figures.	**1**
	Uncertainties in *X* from ± 0.4 to ± 0.07 (± 0.1). Allow more than one significant figure.	**1**
(c) (i)	Six points plotted correctly. Must be within half a small square. No “blobs”.	**1**
	All error bars in *X* plotted correctly. All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.	**1**
(ii)	Line of best fit drawn. Line must not be drawn from top point to bottom point. The lower end of line should pass between (0.95, 0.45) and (1.1, 0.45) **and** upper end of line should pass between (2.10, 0.70) and (2.25, 0.70).	**1**
	Worst acceptable line drawn correctly. Steepest or shallowest possible line that passes through <u>all</u> the error bars. Mark scored only if all error bars are plotted.	**1**
(iii)	Gradient determined with a triangle that is at least half the length of the drawn line. Read-offs must be accurate to half a small square.	**1**
	Method of determining absolute uncertainty. uncertainty = gradient of line of best fit – gradient of worst acceptable line *or* uncertainty = ½(steepest worst line gradient – shallowest worst line gradient)	**1**
(iv)	y-intercept determined correctly by substitution into $y = mx + c$. Read-offs must be accurate to half a small square.	**1**

Question	Answer	Marks
	Method of determining absolute uncertainty. uncertainty = *y*-intercept of line of best fit – *y*-intercept of worst acceptable line *or* uncertainty = ½(steepest worst line *y*-intercept – shallowest worst line *y*-intercept) No ECF from false origin method.	**1**
(d) (i)	*E* = 1/*y*-intercept <u>and</u> given to 2 or 3 s.f.	**1**
	$Y = \frac{1}{E \times \text{gradient}}$ *or* $\frac{y - \text{intercept}}{\text{gradient}}$ *Y* in the range (0.90 to 1.20) × 10^{-3} F. Appropriate unit required. Correct substitution of numbers must be seen.	**1**
(ii)	Percentage uncertainty in *Y* $= \left(\frac{\Delta m}{m} + \frac{\Delta c}{c}\right) \times 100$ *or* $= \left(\frac{\Delta m}{m} + \frac{\Delta E}{E}\right) \times 100$ *or* $= \frac{\Delta Y}{Y} \times 100$ Maximum/minimum methods: $\max Y = \frac{1}{\min E \times \min \text{gradient}} = \frac{\max y - \text{intercept}}{\min \text{gradient}}$ $\min Y = \frac{1}{\max E \times \max \text{gradient}} = \frac{\min y - \text{intercept}}{\max \text{gradient}}$	**1**

Question	Answer	Marks
7(a)	gradient = $-C\ln\left(1-\frac{V}{E}\right)$ **or** $C\ln\left(\frac{E}{E-V}\right)$	**1**
(b)	see table below	**2**
(c)(i)	Six points plotted correctly. Must be within half a small square. Diameter of points must be less than half a small square.	**1**
	Error bars in *nR* plotted correctly. All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.	**1**
(c)(ii)	Line of best fit drawn. Upper end of line should pass between (25, 90) and (26, 90) **and** lower end of line should pass between (10.5, 40) and (11.5, 40). Do not allow line from top point to bottom point unless points are balanced.	**1**
	Worst acceptable line drawn (steepest or shallowest possible line). All error bars must be plotted.	**1**

Table for (b):

$nR / 10^3\,\Omega$	absolute uncertainty in *nR*
4.7 or 4.70	0.5 or 0.47
9.4 or 9.40	0.9 or 0.94
14 or 14.1	1 or 1.4 or 1.41
19 or 18.8	2 or 1.9 or 1.88
24 or 23.5	2 or 2.4 or 2.35
28 or 28.2	3 or 2.8 or 2.82

First mark for correct column heading and values of *nR*.
Second mark for absolute uncertainties in *nR*. Allow a mixture of significant figures.

Question	Answer	Marks
(c)(iii)	Gradient determined with clear substitution of points from the line of best fit into $\Delta y / \Delta x$. Distance between points must be at least half the length of the drawn line.	**1**
	Gradient of worst acceptable line determined. uncertainty = gradient of line of best fit – gradient of worst acceptable line **or** uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)	**1**
(d)(i)	*C* determined using gradient **and** given to 2 or 3 significant figures.	**1**
	C determined using: $C = \frac{-\text{gradient}}{\ln\left(1-\frac{V}{E}\right)} = \frac{-\text{(c)(iii)}}{\ln(0.2)} = \frac{-\text{(c)(iii)}}{-1.609438}$	**1**
	C determined correctly using gradient **and** with unit (F or $\text{s}\,\Omega^{-1}$) **and** correct power of ten.	**1**
(d)(ii)	% uncertainty in *C* = % uncertainty in gradient.	**1**

Question	Answer	Marks
(e)	*K* determined using *C*. Correct substitution of numbers must be seen. $K = \frac{-300}{\ln(1-0.9)\times C} = \frac{-300}{-2.30\times(\text{d})(\text{i})} = \frac{130.3}{(\text{d})(\text{i})}$	**1**
	Absolute uncertainty in *K* determined. Correct substitution of numbers must be seen. $\text{uncertainty} = \left(\frac{\Delta\text{gradient}}{\text{gradient}}\right)\times K = \left(\frac{\Delta C}{C}\right)\times K$ Maximum/minimum methods: $\max K = \frac{-130.3}{\min\ (\text{d})(\text{i})} = \frac{-130.3\times -1.609}{\min\ \text{gradient}} = \frac{209.69}{\min\ \text{gradient}}$ $\min K = \frac{-130.3}{\max\ (\text{d})(\text{i})} = \frac{-130.3\times -1.609}{\max\ \text{gradient}} = \frac{209.69}{\max\ \text{gradient}}$	**1**

Question	Answer	Marks
8(a)	gradient = $\frac{-1}{CR}$ y-intercept = $\ln \frac{Q_0}{C}$	**1**
(b)	ln (V / V) 1.82 or 1.825 1.53 or 1.526 1.22 or 1.224 0.96 or 0.956 0.69 or 0.693 0.34 or 0.336	**1**
	Absolute uncertainties in ln V from ± 0.03 or ± 0.04 to ± 0.13 or ± 0.14 or ± 0.15.	**1**
(c)(i)	Six points plotted correctly. Must be within half a small square. Diameter of points must be less than half a small square.	**1**
	Error bars in ln V plotted correctly. All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.	**1**
(c)(ii)	Line of best fit drawn. Points must be balanced. Do not accept top point to bottom point. Line must pass between (4.0, 1.6) and (5.0, 1.6) **and** between (26.5, 0.5) and (28.0, 0.5)	**1**
	Worst acceptable line drawn (steepest or shallowest possible line that passes through all the error bars). All error bars must be plotted.	**1**

Question	Answer	Marks
(c)(iii)	Gradient determined with clear substitution of data points into $\Delta y / \Delta x$. Distance between data points must be at least half the length of the drawn line. Gradient must be negative.	**1**
	uncertainty = (gradient of line of best fit – gradient of worst acceptable line) or uncertainty = ½ (steepest worst line gradient – shallowest worst line gradient)	**1**
(c)(iv)	*y*-intercept read from *y*-axis to less than half a small square **or** *y*-intercept determined from substitution into $y = mx + c$.	**1**
(d)(i)	C determined using gradient **and** C and Q_0 given to two or three significant figures. Correct substitution of numbers required. $C = \frac{-1}{39 \times 10^3 \times \text{gradient}} = \frac{-1}{39 \times 10^3 \times \textbf{(c)(iii)}}$	**1**
	Q_0 determined using *y*-intercept. $Q_0 = C \times e^{y\text{-intercept}} = C \times e^{\textbf{(c)(iv)}}$	**1**
	C determined using gradient **and** Q_0 determined using *y*-intercept **and** dimensionally correct units for C (F or $\text{s}\,\Omega^{-1}$) and Q_0 (C or $\text{V}\,\text{s}\,\Omega^{-1}$ or A s).	**1**
(d)(ii)	Absolute uncertainty in C. $\Delta C = \left(0.05 + \frac{\Delta\text{gradient}}{\text{gradient}}\right) \times C$	**1**

Question	Answer	Marks
8(e)	V determined from **(d)(i)** (**or (c)(iii)** and **(c)(iv)**) with correct substitution shown and correct power of ten. $V = \frac{Q_0}{C} \times e^{\frac{-60}{CR}} = e^{y\text{-intercept}} \times e^{(\text{gradient} \times 60)}$ **or** ln V = – (t / RC) + ln (Q_0 / C) = – (60 / 39 000) × **(d)(i)** + ln (Q_0 / C) ln V = 60 × gradient + y-intercept ln V = 60 × **(c)(iii)** + **(c)(iv)**	**1**