

Question	Answer	Marks
1	Defining the problem	
	x is the independent variable and E is the dependent variable, or vary x and measure E .	1
	Keep B or m <u>constant</u> <u>and</u> keep k or N <u>constant</u> .	1
	Methods of data collection	
	Labelled diagram of workable experiment including: <ul style="list-style-type: none"> labelled spring supported by stand and clamp labelled magnet labelled coil positioned so that magnet is vertically above the coil by eye in the correct orientation. 	1
	Circuit diagram showing voltmeter / multimeter set to p.d. range / oscilloscope connected to the ends of the coil. Do not accept other electrical components.	1
	Method to measure x , e.g. labelled ruler drawn parallel to spring/magnet <u>and</u> equilibrium position <u>and</u> displaced position indicated <u>and</u> x indicated or difference determined or description of use of ruler to measure equilibrium position <u>and</u> displaced position <u>and</u> difference determined.	1
	Method to measure mass of magnet e.g. use balance or use newton-meter to measure weight and divide by g .	1
	Method of Analysis	
	Plots a graph of E against x or equivalent. Allow $\lg E$ against $\lg x$.	1
	Relationship valid <u>if</u> a straight line passing through the origin is produced. (for $\lg E$ against $\lg x$: relationship valid <u>if</u> a straight line with gradient = 1).	1
	$\alpha = \frac{\text{gradient}}{BN} \sqrt{\frac{m}{k}}$ (for $\lg E$ against $\lg x$: $\alpha = \frac{10^{y\text{-intercept}}}{BN} \sqrt{\frac{m}{k}}$)	1

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1	Additional detail including safety considerations	Max 6
	Use safety goggles / safety screen to prevent injury (to eyes) from (detached) spring/magnet; do not accept from oscillating magnet or use cushion / sand box <u>in case magnet falls</u> or use g clamp / weights on stand <u>to prevent toppling</u> .	D1
	Keep distance between equilibrium position and coil <u>constant</u> .	D2
	Check that the unstretched length of the spring has not changed or is not permanently deformed (after removing load / magnet).	D3
	Expression to determine k from relevant experiment, e.g. $k = mg / \text{extension}$ or gradient of $F - \text{extension}$ graph. Weight / force must be defined.	D4
	Measure B using a (calibrated) Hall probe.	D5
	Additional detail on use of Hall probe, e.g. adjust probe until maximum value or measure B using Hall probe first in one direction and then in the opposite direction and average.	D6
	Method to maximise E , e.g. position magnet so that equilibrium position is at the centre of the coil or use a large number of turns.	D7
	Explanation to determine max E e.g. use of video and slow-motion playback.	D8
	Repeat experiment for each x and average E .	D9
	Method to ensure <u>clamped rule to measure x</u> is vertical, e.g. correctly positioned set square indicated at right angles between the rule <u>and</u> the horizontal surface or plumb line supported on a surface shown in appropriate position.	D10



Question	Answer	Marks						
2(a)	Gradient = $\frac{-1}{CR}$ y-intercept = $\ln \frac{E}{R}$	1						
2(b)	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr><td>3.83 or 3.829</td></tr> <tr><td>3.69 or 3.689</td></tr> <tr><td>3.53 or 3.526</td></tr> <tr><td>3.33 or 3.332</td></tr> <tr><td>3.18 or 3.178</td></tr> <tr><td>3.00 or 2.996</td></tr> </table>	3.83 or 3.829	3.69 or 3.689	3.53 or 3.526	3.33 or 3.332	3.18 or 3.178	3.00 or 2.996	1
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	Absolute uncertainties in $\ln I$ from ± 0.04 to ± 0.1	1						
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 $\ln I$ plotted correctly. All error bars to be plotted. Total length of bar must be accurate to less than half a small square and symmetrical.	1						
2(c)(ii)	Line of best fit drawn. Points must be balanced. Line must pass between (5.5, 3.75) and (8.0, 3.75) <u>and</u> between (56, 3.05) and (58, 3.05)	1						
	Worst acceptable line drawn. Steepest or shallowest possible line that passes through all the error bars. Mark scored only if all error bars are plotted.	1						

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2(c)(iii)	<u>Negative</u> 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.	1
	Gradient determined of WAL uncertainty = (gradient of line of best fit – gradient of worst acceptable line) or uncertainty = $\frac{1}{2}$ (steepest worst line gradient – shallowest worst line gradient)	1
2(c)(iv)	y-intercept read from y-axis to less than half a small square, or y-intercept determined from substitution into $y = m x + c$.	1
2(d)(i)	C determined using gradient <u>and</u> C given to two or three significant figures Correct substitution of numbers must be seen, $C = \frac{-1}{150 \times 10^3 \times \text{gradient}} = \frac{-1}{150 \times 10^3 \times (c)(iii)}$	1
	E determined using y-intercept Correct substitution of numbers must be seen, $E = R \times e^{y\text{-intercept}} = 150 \times 10^3 \times e^{(c)(iv)} (\times 10^{-6})$ Or $\ln E = \ln R + y\text{-intercept}$	1
	C determined using gradient <u>and</u> E determined using y-intercept <u>and</u> dimensionally correct SI unit for C: F or $s \Omega^{-1}$ or $C V^{-1}$ or $A s V^{-1}$ and E: V or $A \Omega$.	1



Question	Answer	Marks
2(d)(ii)	Absolute uncertainty in C . $\Delta C = \left(0.05 + \frac{\Delta \text{gradient}}{\text{gradient}} \right) \times C$ OR Correct substitution for max/min methods $\max C = \frac{-1}{142.5 \times 10^3 \times \text{min numerical gradient}}$ $\min C = \frac{-1}{157.5 \times 10^3 \times \text{max numerical gradient}}$	1
2(e)	<i>I</i> determined from (d)(i) OR (c)(iii) and (c)(iv) with correct substitution <u>and</u> correct power of ten(s). Do not accept ecf for POT from (c)(iii) , (iv) or (d) . $I = \frac{E}{R} \times e^{\frac{-120}{CR}}$ OR $I = e^{y\text{-intercept}} \times e^{(\text{gradient} \times 120)} \times 10^{-6}$ OR $\ln I = 120 \times \text{gradient} + y\text{-intercept}$ $I = e^{120 \times \text{gradient} + y\text{-intercept}} \times 10^{-6}$	1

