

Question	Answer	Marks
1	**Defining the problem**	
	A is the independent variable and *k* is the dependent variable **or** vary *A* and measure *k*	**1**
	keep *N* constant	**1**
	Methods of data collection	
	labelled diagram of workable experiment including: • spring fixed at one end to a support • load attached to the other end of the spring • labelled load	**1**
	method to measure mass or weight of load: use top-pan balance to measure mass or newton meter to measure weight	**1**
	use of a micrometer/calipers to determine *t* **and** rule/calipers to measure the diameter of the spring	**1**
	method to measure extension, e.g. labelled ruler drawn parallel to spring, equilibrium position and displaced position indicated and *x* indicated **or** description of use of ruler to measure equilibrium position and displaced position and difference determined	**1**
	Method of analysis	
	plot a graph of *k* against $1/A^{3/2}$ (or $A^{-3/2}$) or equivalent e.g. lg *k* against lg *A*	**1**
	relationship valid if a straight line passing through the origin is produced (for lg *k* against lg *A*, relationship valid if a straight line with gradient –3/2)	**1**
	$\beta = \dfrac{\text{gradient} \times N}{\rho t^4}$ [for lg *k* against lg *A*, $\beta = 10^{y\text{-intercept}} \times N / (\rho t^4)$]	**1**

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1	**Additional detail including safety considerations**	**6**
	D1 use safety goggles/safety screen to prevent injury to eyes from (moving) spring/load **or** use cushion/sand box in case load falls	
	D2 keep *t* constant	
	D3 $k = \frac{mg}{x}$ or $\frac{F}{x}$	
	D4 use of set square when taking measurements to determine extension of spring	
	D5 repeat measurement of *t* along wire/spring and average	
	D6 repeat measurement of diameter *D* of spring (to determine *A*) in different directions and average	
	D7 use of $A = \frac{\pi D^2}{4}$	
	D8 method to ensure clamped rule to measure extension is vertical, e.g. correctly positioned set square indicated at right angles between the rule and the horizontal surface **or** plumb line shown in appropriate position	
	D9 method to determine the density of the wire **or** additional detail on construction of coil	
	D10 method to determine the mean diameter of the spring, e.g. subtract *t* from external diameter of spring	

Question	Answer	Marks
2(a)	gradient = $\dfrac{-1}{CR}$ y-intercept = $\ln \dfrac{Q_0}{C}$	**1**
2(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**
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 *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**
2(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**

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2(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**
2(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**
2(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 $\mathrm{s\,\Omega^{-1}}$) and Q_0 (C or $\mathrm{V\,s\,\Omega^{-1}}$ or A s).	**1**
2(d)(ii)	Absolute uncertainty in C. $\Delta C = \left(0.05 + \frac{\Delta\text{gradient}}{\text{gradient}}\right) \times C$	**1**

Question	Answer	Marks
2(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** $\ln V = -(t / RC) + \ln(Q_0 / C) = -(60 / 39\,000) \times$ **(d)(i)** $+ \ln(Q_0 / C)$ $\ln V = 60 \times \text{gradient} + y\text{-intercept}$ $\ln V = 60 \times$ **(c)(iii)** + **(c)(iv)**	**1**