Question	Answer	Marks
1	**Defining the problem**	
	R is the independent variable and *t* is the dependent variable **or** vary *R* and measure *t*	**1**
	keep the number of turns on the coil/*N* constant	**1**
	Methods of data collection	
	labelled diagram or correct symbols including: • labelled (d.c.) power supply • switch in series with power supply, resistor and coil • complete workable circuit	**1**
	circuit diagram to measure *R*, e.g. ammeter and voltmeter correctly positioned **or** *R* connected to ohmmeter with no other connections (**not** ohmmeter in main circuit)	**1**
	method to determine *t* (of a few milliseconds) e.g. use (storage) oscilloscope **or** current/voltage sensor connected to datalogger/computer	**1**
	method to determine *A*, e.g. micrometer/calipers to determine diameter of coil **and** $A = \pi d^2 / 4$	**1**
	Method of analysis	
	plot a graph of *t* against 1 / *R* (allow log *t* against log *R*)	**1**
	relationship valid if a straight line passing through the origin is produced (allow gradient = –1 for graph of log *t* against log *R*)	**1**
	$K = \dfrac{\text{gradient} \times L}{AN^2}$.	**1**

Question	Answer	Marks
1	**Additional detail including safety considerations**	**6**
	D1 open switch/switch off (high voltage) circuit before changing the resistor/touching components **or** ensure no bare wires/use shrouded connectors	
	D2 wear (insulating) gloves to prevent electric shock/electrocution	
	D3 keep *A* and *L* constant	
	D4 use ruler/calipers to measure *L*	
	D5 repeat measurements of diameter in different directions/at points along the coil and average	
	D6 method to determine *R* e.g. $R = V / I$ linked to correct circuit diagram for ammeter/voltmeter method **or** measure resistance using ohmmeter	
	D7 repeat experiment for each value of *R* and average *t*	
	D8 method to determine *t*: use of time-base from oscilloscope explained **or** use of time axis of output from data logger/computer explained	
	D9 use smaller values of *R* to increase *I*	
	D10 reduce *L* or increase *N* or increase *A* to increase *t*	

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>2(a)</td><td>gradient = $\frac{1}{uA}$
y-intercept = $\frac{1}{u}$</td><td>1</td></tr>
<tr><td>2(b)</td><td><table><tr><th>$(M + m)$ / g</th><th>$\frac{1}{v}$ / s cm^{-1}</th></tr><tr><td>380</td><td>0.226 or 0.2262</td></tr><tr><td>480</td><td>0.255 or 0.2551</td></tr><tr><td>580</td><td>0.294 or 0.2941</td></tr><tr><td>680</td><td>0.331 or 0.3311</td></tr><tr><td>830</td><td>0.388 or 0.3876</td></tr><tr><td>930</td><td>0.429 or 0.4292</td></tr></table>Values of $(M + m)$ and $\frac{1}{v}$ as shown above.</td><td>1</td></tr>
<tr><td></td><td>Absolute uncertainties in $(M + m)$ from ± (19 or 20) to ± (46.5 or 47 or 50).</td><td>1</td></tr>
<tr><td>2(c)(i)</td><td>Six points plotted correctly.
Must be accurate to the nearest half a small square. Diameter of points must be less than half a small square.</td><td>1</td></tr>
<tr><td></td><td>Error bars in $(M + m)$ plotted correctly.
All error bars must be plotted. Total length of bar must be accurate to less than half a small square and symmetrical.</td><td>1</td></tr>
</table>

Question	Answer	Marks
2(c)(ii)	Line of best fit drawn covers all points. Points must be balanced. Do not allow line from top point to bottom point. Line must pass between (425, 0.240) and (440, 0.240) **and** between (850, 0.400) and (865, 0.400).	**1**
	Worst acceptable line drawn (steepest or shallowest possible line that passes through all error bars). All error bars must be plotted.	**1**
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.	**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**
2(c)(iv)	*y*-intercept determined by substitution of correct point into $y = mx + c$.	**1**
	y-intercept of worst acceptable line determined by substitution into $y = mx + c$. 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) Do not allow ECF from false origin method.	**1**
2(d)(i)	*u* determined using *y*-intercept **and** *u* and *A* given to two or three significant figures. $u = \frac{1}{y\text{-intercept}}$	**1**
	A determined using gradient with correct substitution **and** units with correct power of ten for *u* and *A*. $A = \frac{y\text{-intercept}}{\text{gradient}}$ **or** $A = \frac{1}{u \times \text{gradient}}$	**1**

Question	Answer	Marks
2(d)(ii)	Percentage uncertainty in A determined, e.g. $\text{percentage uncertainty in } A = \left(\frac{\Delta\text{gradient}}{\text{gradient}} + \frac{\Delta y\text{-intercept}}{y\text{-intercept}}\right)$ **or** Δu clearly determined using the value of u and $\text{percentage uncertainty in } A = \left(\frac{\Delta\text{gradient}}{\text{gradient}} + \frac{\Delta u}{u}\right) \times 100$ **or** correct substitution for max/min methods e.g. $\max A = \frac{1}{\min u \times \min \text{ gradient}}$ $\min A = \frac{1}{\max u \times \max \text{gradient}}$	**1**
2(e)	Value of m determined from **(d)(i) or (c)(iii)** and **(c)(iv)**, with correct number substitution and correct power of ten. $m = \frac{A \times u}{2} - (330 + A)$ **or** $m = \frac{0.5 - y\text{-intercept}}{\text{gradient}} - 330$	**1**