Question	Answer	Marks
1	**Defining the problem**	
	Mass of cylinder *m* is the independent variable and period *T* is the dependent variable, or vary mass of cylinder *m* and measure period *T*.	**1**
	Keep radius of cylinder constant.	**1**
	Methods of data collection	
	Labelled diagram of workable experiment including: • beaker with (cooking) oil on a bench or container supported by stand where stand is on a bench • cylinder partially submerged in (cooking) oil • cylinder and (cooking) oil labelled.	**1**
	Method to determine mass *m* of cylinder, e.g. use a (top pan) balance.	**1**
	Method to determine period or *T*, e.g. use a stopwatch / timer to time oscillations.	**1**
	Method to determine diameter of cylinder, e.g. micrometer or calliper	**1**
	Method of Analysis	
	Plots a graph of T^2 against *m*. (Allow other valid graphs, e.g. lg *T* against lg *m*)	**1**
	Relationship valid if a straight line passing through the origin is produced. (Allow gradient = 0.5 for log *T* against log *m*).	**1**
	$K = \dfrac{4\pi}{\text{gradient} \times \sigma r^2}$ ($K = \dfrac{4\pi}{10^{2\times\text{y-intercept}} \times \sigma r^2}$ for lg *T* against lg *m*).	**1**

Question	Answer	Marks
1	**Additional detail including safety considerations** **Max 6**	**6**
	Use gloves to prevent oil contacting skin / slippery hands OR Perform experiment in a tray to prevent oil spillages.	D1
	Keep density / temperature of the (cooking) oil constant or keep σ constant.	D2
	Mass of oil = mass of beaker and oil – mass of beaker and use a measuring cylinder to determine the volume of the oil. Do not accept (calibrated) beaker.	D3
	Methods to measure volume of oil and determine mass of oil and use equation density σ = mass / volume for measurements.	D4
	Time n oscillations and divide nT by n where $n \geqslant 5$.	D5
	Description of method of counting oscillations with position of fiducial mark / mark on cylinder / beaker / fixed point shown in diagram.	D6
	Repeat experiment for each value of m and average T.	D7
	r = diameter / 2 provided diameter measured.	D8
	Repeat measurements of diameter in different directions and average.	D9
	Wait for oscillations to become even / steady.	D10

Question	Answer	Marks
2(a)	Gradient = $\frac{1}{2uA}$ y-intercept = $\frac{1}{2u}$.	**1**
2(b)	0.046 0.052 0.062 0.072 0.080 0.088	
	First mark for values of $\frac{1}{v}$ / s cm^{-1}; allow 3sf.	**1**
	Second mark for absolute uncertainties from ± 0.003 to ± 0.004.	**1**
2(c)(i)	Six points plotted correctly. Must be accurate to the nearest half small square. Diameter of points must be less than half a small square.	**1**
	Error bars in $\frac{1}{v}$ 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**

Question	Answer	Marks
2(c)(ii)	Line of best fit drawn. Points must be balanced. Do not allow line from top plot to bottom plot. Line must pass between (320, 0.050) and (345, 0.050) **and** between (795, 0.085) and (815, 0.085).	**1**
	Worst acceptable line drawn. Steepest or shallowest possible line. Mark scored only if all error bars are 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 WAL determined and 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 accept ecf from false origin method.	**1**

Question	Answer	Marks
2(d)(i)	*u* determined using *y*-intercept and *u* and *A* given to 2 or 3 sf. $u = \frac{1}{2 \times y - \text{intercept}}$	**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 $A = \frac{1}{2 \times u \times \text{gradient}}$	**1**
2(d)(ii)	Percentage uncertainty in *A*. $\%\text{uncert.} = \left(\frac{\Delta\text{gradient}}{\text{gradient}} + \frac{\Delta y\text{-intercept}}{y\text{-intercept}}\right) \times 100$ OR Δu clearly determined and $\%\text{uncert.} = \left(\frac{\Delta\text{gradient}}{\text{gradient}} + \frac{\Delta u}{u}\right) \times 100$ OR Correct substitution for max/min methods.	**1**
2(e)	Value of *m* determined from **(d)(i)** OR **(c)(iii)** and **(c)(iv)** with correct number substitution into relevant equation and correct power of ten. e.g. $m = \frac{2uAt}{L} - A = \frac{2uA}{10} - A$, or $m = \left(\frac{t}{L} - \frac{1}{2u}\right) \times 2uA$ or $m = \frac{\frac{t}{L} - y\text{-intercept}}{\text{gradient}}$.	**1**