Question	Answer	Marks
1	**Defining the problem**	
	A is the independent variable and *f* is the dependent variable **or** vary *A* and measure *f*	**1**
	keep *M* constant	**1**
	Methods of data collection	
	labelled diagram of workable experiment including: • elastic cord fixed at one end to a support • other end passed over a pulley • labelled pulley • labelled load	**1**
	vibrator connected to signal generator	**1**
	increase/decrease the frequency of the signal generator until stationary wave pattern is observed	**1**
	measure diameter of cord with micrometer/calipers	**1**
	Method of analysis	
	plot a graph of f^2 against 1 / *A* or equivalent (e.g. lg *f* against lg *A*)	**1**
	relationship valid if a straight line passing through the origin is produced (for lg *f* against lg *A*, relationship valid if a straight line with gradient –½)	**1**
	$k = \frac{M}{\text{gradient} \times 4 \times L^2}$ (for lg *f* against lg *A*, $k = M / [10^{(2 \times y\text{-intercept})} \times 4 \times L^2]$)	**1**

Question	Answer	Marks
1	**Additional detail including safety considerations**	**6**
	D1 use safety goggles/safety screen to prevent injury to eyes from (moving) elastic cord/load **or** use cushion/sand box in case load falls	
	D2 keep L constant	
	D3 use cords of the same material/density	
	D4 use CRO to determine f (or T)	
	D5 method to determine T from CRO, e.g. period = time base $\times$ length of one wave	
	D6 $f = 1 / T$	
	D7 repeat measurement of diameter along cord and average	
	D8 use of $A = \frac{\pi d^2}{4}$	
	D9 measure mass of the load on top-pan balance	
	D10 detail on determining frequency at the maximum amplitude, e.g. increase frequency until the amplitude starts to decrease, then decrease frequency	

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>2(a)</td><td>gradient = $\frac{4\mu L^2 f^2}{g}$</td><td>1</td></tr>
<tr><td>2(b)</td><td><table><tr><th>M / g</th><th>$\frac{1}{n^2}$</th></tr><tr><td>850 ± 85 (90)</td><td>0.1 or 0.11 or 0.111 or 0.1111</td></tr><tr><td>500 ± 50</td><td>0.06 or 0.063 or 0.0625</td></tr><tr><td>300 ± 30</td><td>0.04 or 0.040 or 0.0400</td></tr><tr><td>200 ± 20</td><td>0.03 or 0.028 or 0.0278</td></tr><tr><td>150 ± 15 (20)</td><td>0.02 or 0.020 or 0.0204</td></tr><tr><td>100 ± 10</td><td>0.02 or 0.016 or 0.0156</td></tr></table>
First mark for uncertainties in first column correct.
Second mark for all second column correct.</td><td>2</td></tr>
<tr><td rowspan="2">2(c)(i)</td><td>Six points plotted correctly.
Must be within half a small square. Diameter of points must be less than half a small square.</td><td>1</td></tr>
<tr><td>Error bars in M plotted correctly.
All error bars to be plotted. Length of bar must be accurate to less than half a small square and symmetrical.</td><td>1</td></tr>
<tr><td rowspan="2">2(c)(ii)</td><td>Line of best fit drawn.
Line must not pass through plotted point (0.11, 850) or (0.111, 850).

If points are plotted correctly then lower end of line should pass between (0.032, 250) and (0.036, 250) and upper end of line should pass between (0.098, 800) and (0.104, 800).</td><td>1</td></tr>
<tr><td>Worst acceptable line drawn (steepest or shallowest possible line).
All error bars must be plotted.</td><td>1</td></tr>
</table>

Question	Answer	Marks
2(c)(iii)	Gradient determined with a triangle that is at least half the length of the drawn line.	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(d)(i)	μ determined correctly using gradient. $\mu = \frac{9.81}{4 \times 120^2 \times 1.54^2} \times \text{gradient}$ $\mu = 7.18123 \times 10^{-5} \times \text{gradient}$	1
	μ determined using gradient **and** given to 2 or 3 significant figures.	1
	μ determined using gradient **and** correct unit g m^{-1} **and** in the range 0.560–0.630 (g m^{-1}).	1

Question	Answer	Marks
2(d)(ii)	Percentage uncertainty in μ. $\% \text{ uncertainty} = \left(2 \times \frac{0.01}{1.54} + 2 \times \frac{5}{120} + \frac{\Delta\text{gradient}}{\text{gradient}}\right) \times 100$ $\% \text{ uncertainty} = 9.63\% + \frac{\Delta\text{gradient}}{\text{gradient}} \times 100$ Maximum/minimum methods: $\max \mu = \frac{9.81 \times \text{max gradient}}{4 \times 115^2 \times 1.53^2}$ $\min \mu = \frac{9.81 \times \text{min gradient}}{4 \times 125^2 \times 1.55^2}$ Correct substitution of numbers must be seen.	**1**

Question	Answer	Marks
2(e)	*M* determined correctly using μ from **(d)(i)**. $M = \frac{180^2 \times 1.54^2 \times \textbf{(d)(i)}}{9.81 \times 1000} = 7.833 \times \textbf{(d)(i)}$ Correct substitution of numbers must be seen.	**1**
	Absolute uncertainty determined. $\% \text{ uncertainty} = \left(2 \times \frac{0.01}{1.54} + 2 \times \frac{5}{180}\right) \times 100 + \textbf{(d)(ii)} = 6.9\% + \textbf{(d)(ii)}$ Correct substitution of numbers must be seen. Maximum/minimum methods: $\text{max } M = \frac{(4 \times) 185^2 \times 1.55^2 \times \text{max}\textbf{(d)(i)}}{(4 \times) 9.81 \times 1000} = 8.382 \times \text{max}\textbf{(d)(i)}$ $\text{min } M = \frac{(4 \times) 175^2 \times 1.53^2 \times \text{min}\textbf{(d)(i)}}{(4 \times) 9.81 \times 1000} = 7.308 \times \text{min}\textbf{(d)(i)}$	**1**