Question	Answer	Marks
1	**Defining the problem**	
	m is the independent variable and θ is the dependent variable **or** vary *m* and measure θ **or** θ is the independent variable and *m* is the dependent variable **or** vary θ and measure *m*	**1**
	keep position of load constant or *L* constant	**1**
	Methods of data collection	
	labelled diagram of workable experiment including: • load shown touching at P • load labelled and at least one other label	**1**
	use a protractor to measure θ	**1**
	if *m* is the independent variable: (slowly) change the angle until the block (just) topples **or** if θ is the independent variable: (slowly) change mass until block (just) topples	**1**
	use a balance to measure *m*	**1**

Question	Answer	Marks
1	**Method of analysis**	
	plot a graph of cos θ against 1 / m (**or** reverse axes 1 / m against cos θ) (**not** 1 / cos θ against m or m against 1 / cos θ)	**1**
	relationship valid if a straight line (**not** 'through the origin' unless the choice of axes indicates the intercept is zero)	**1**
	$\alpha = \dfrac{2L \times \text{gradient}}{V \times w}$ **or** $\alpha = \dfrac{\text{gradient}}{V \times y\text{-intercept}}$ for reverse axes: $\alpha = \dfrac{2L}{V \times w \times \text{gradient}}$ **or** $\alpha = -\dfrac{1}{V \times y\text{-intercept}}$	**1**

Question	Answer		Marks
1	**Additional detail including safety considerations**		**Max. 6**
	D1	use cushion/foam/sandbox in case block/load falls	
	D2	measure L with a rule	
	D3	correctly positioned protractor to measure θ, e.g. protractor with its centre over the nail and its straight edge parallel to an edge of the block	
	D4	method to fix m to strip	
	D5	method to determine volume of block, e.g. $V = w \times h \times l$	
	D6	measure w, h and l with calipers/micrometer/rule	
	D7	(if m is the independent variable:) repeat experiment for θ and determine the average θ **or** (if θ is the independent variable:) repeat experiment for m and determine the average m	
	D8	equation must be in the form of $y = mx + c$ with cos θ on one side and m on the other side e.g. for a graph of cos θ against 1 / m $\cos\theta = \frac{\alpha V w}{2Lm} + \frac{w}{2L}$ or for a graph of 1 / m against cos θ $\frac{1}{m} = \frac{2L\cos\theta}{\alpha V w} - \frac{1}{\alpha V}$	
	D9	method to determine centre of load or centre of block e.g. measure diameter/width and halve or diagonals across the block	
	D10	method to ensure that block or strip is horizontal, e.g. check with a spirit level that table/block is horizontal or use a rigid strip	

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>2(a)</td><td>gradient = $4\pi^2 M$</td><td>1</td></tr>
<tr><td rowspan="5">2(b)</td><td><table><tr><th>T / s</th><th>T^2 / s^2</th></tr><tr><td>1.12 or 1.120</td><td>1.25 or 1.254</td></tr><tr><td>0.950 or 0.9500</td><td>0.903 or 0.9025</td></tr><tr><td>0.815 or 0.8150</td><td>0.664 or 0.6642</td></tr><tr><td>0.655 or 0.6550</td><td>0.429 or 0.4290</td></tr><tr><td>0.570 or 0.5700</td><td>0.325 or 0.3249</td></tr><tr><td>0.47 or 0.470</td><td>0.22 or 0.221</td></tr></table></td><td></td></tr>
<tr><td>Values of T as above.</td><td>1</td></tr>
<tr><td>Values of T^2 as above.</td><td>1</td></tr>
<tr><td>Uncertainties in T increase from ±0.01 to ±0.02.</td><td>1</td></tr>
<tr><td>Uncertainties in T^2 about ±0.02.</td><td>1</td></tr>
<tr><td rowspan="2">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>Error bars in T^2 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.
If points are plotted correctly then lower end of line should pass between (0.048, 0.5) and (0.052, 0.5) and upper end of line should pass between (0.098, 1.0) and (0.104, 1.0).</td><td>1</td></tr>
<tr><td>Worst acceptable line drawn (steepest or shallowest possible line that passes through all the error bars).
All error bars must be plotted.</td><td>1</td></tr>
</table>

Question	Answer	Marks
2(c)(iii)	Gradient determined with clear substitution of points from the line of best fit into $\Delta y / \Delta x$. Distance between points must be 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)	*M* determined from gradient **and** given to 2 or 3 significant figures **and** with correct unit. $M = \frac{\text{gradient}}{4\pi^2} = \frac{\textbf{(c)(iii)}}{39.478}$	**1**
2(d)(ii)	% uncertainty in *M* = % uncertainty in gradient	**1**

Question	Answer	Marks
2(e)	*k* calculated. Correct substitution of numbers required. $k = \left(\frac{4\pi^2 M}{T^2} =\right) \frac{4\pi^2 \textbf{(d)(i)}}{2.5^2}$ **or** $6.3165 \times$ **(d)(i)** **or** $k = \left(\frac{\text{gradient}}{T^2}\right) = \frac{\textbf{(c)(iii)}}{2.5^2}$ **or** $\frac{\textbf{(c)(iii)}}{6.25}$	**1**
	Absolute uncertainty in *k*. Correct substitution of numbers required. Using *M*: $\text{uncertainty in } k = \left(\frac{\Delta M}{M} + 2 \times \frac{\Delta T}{T}\right) \times k$ $\text{uncertainty in } k = \left(\frac{\textbf{(d)(ii)}}{100} + 0.008\right) \times k$ $\max k = \frac{4\pi^2 \times \max M}{\min T^2}$ **or** $\min k = \frac{4\pi^2 \times \min M}{\max T^2}$ Using gradient: $\text{uncertainty in } k = \left(\frac{\Delta\text{gradient}}{\text{gradient}} + 0.008\right) \times k$ $\max k = \frac{\max \text{gradient}}{\min T^2}$ **or** $\min k = \frac{\min \text{gradient}}{\max T^2}$	**1**