Question	Answer	Marks
1(a)	Value of M with unit and in range 10–100 g.	**1**
	Value of T with unit and in range 0.950–2.00 s.	**1**
	Repeats: At least two measurements of at least 5T.	**1**
1(b)	Six sets of readings of M (different values, may include 0 g) and T (or time) with correct trend (as M increases T increases) and without help from the Supervisor scores 4 marks, five sets scores 3 marks etc.	**4**
	Range: $M_{min} \leqslant 10$ g **and** $M_{max} \geqslant 70$ g.	**1**
	Column headings: Each column heading must contain a quantity and a unit where appropriate. The presentation of quantity and unit conforms to accepted scientific convention e.g. M^2 / g^2.	**1**
	Consistency: All values of raw time must be given to the nearest 0.01s or all to the nearest 0.1 s.	**1**
	Significant figures: Values of T^2 must be given to the same number of s.f. as (or one more than) the number of s.f. in the corresponding T.	**1**
	Calculation: Values of T^2 calculated correctly.	**1**

Question	Answer	Marks
1(c)(i)	Axes: Axes must be labelled with the correct quantities. Scales must be chosen so that the plotted points occupy at least half the graph grid in both *x* and *y* directions. Scale markings are no more than 2 cm apart (one large square). Sensible scales must be used. Scale must not be awkward (e.g. 3:10 or fractions).	**1**
	Plotting of points: All observations in the table must be plotted on the grid. Diameter of plotted points must be less than half a small square. Points must be plotted to an accuracy of half a small square in both *x* and *y* directions.	**1**
	Quality: Trend of points must be positive. All points in the table must be plotted on the grid. It must be possible to draw a straight line that is within $\pm$ 500 g^2 (to scale) on the M^2 axis of all plotted points.	**1**
1(c)(ii)	Line of best fit: 'Best fit' is judged by balance of all points on the grid (at least 5 points) about the candidate's line. There must be an even distribution of points either side of the line along the full length. Lines must not be kinked or thicker than half a small square. Some candidates may choose to identify an anomalous point. If they identify **one** point as anomalous (e.g. by circling or labelling) then this point is to be disregarded when judging the line of best fit. There must be at least 5 points left after the anomalous point is disregarded.	**1**
1(c)(iii)	Gradient: The hypotenuse of the triangle used should be greater than half the length of the drawn line. Both read-offs must be accurate to half a small square in both *x* and *y* directions. The method of calculation must be correct, not $\Delta x / \Delta y$. The gradient sign on the answer line must be consistent with the graph drawn.	**1**
	y-intercept: Intercept read directly from the graph, with read-off at $M^2 = 0$, accurate to half a small square in *y* direction. **or** Correct read-off from a point on the line and substituted correctly into $y = mx + c$ or an equivalent expression. Read-off is accurate to half a small square in both *x* and *y* directions.	**1**

Question	Answer	Marks
1(d)	Value of a = candidate's gradient **and** value of b = candidate's intercept. Values must not be written as fractions or given to only one significant figure.	**1**
	Correct units for a and b (e.g. s^2g^{-2} for a and s^2 for b).	**1**

Question	Answer	Marks
2(a)	Value for L with unit, to nearest mm and in range 11.7–12.7 cm.	1
	Value for T_0 with unit and to nearest degree.	1
2(b)(i)	Value for x_1 with unit and to nearest mm.	1
2(b)(ii)	Value for T greater than T_0.	1
	Value of x_2 different from x_1.	1
2(b)(iii)	Correct calculation of $(x_1 - x_2)$.	1
2(b)(iv)	Percentage uncertainty in $(x_1 - x_2)$ based on absolute uncertainty in the range 0.2–0.5 cm. Correct method of calculation to obtain percentage uncertainty e.g. (absolute uncertainty / value from **(b)(iii)**) × 100. If several readings have been taken, then the absolute uncertainty can be half the range (but not zero) provided the working is shown clearly.	1
2(c)	Second values of L, x_1, T and x_2.	1
	Second L less than first L.	1
2(d)(i)	Two values of k calculated correctly. The final k values must not be written as fractions.	1
2(d)(ii)	Justification for significant figures in k linked to significant figures in $(x_1 - x_2)$, L and $(T - T_0)$.	1
2(e)	Calculation of percentage difference between candidate's two k values. Comparison of percentage difference with 20% leading to a consistent conclusion.	1

Question	Answer	Marks
2(f)(i)	A Two readings are not enough to draw a (valid) conclusion (**not** "not enough for accurate results", "few readings"). B Difficult to measure x or height with a reason e.g. rod moves/rule not vertical/ruler moves. C $(x_1 - x_2)$ is small so large uncertainty **or** large % uncertainty in $(x_1 - x_2)$. D Difficult to measure T or water temperature with a reason e.g. T varies with position in measuring cylinder/thermometer touches sides of cylinder/cannot measure x and T at the same time/T decreases rapidly. E T_0 or room temperature may change during the experiment. F Difficulty with pipe e.g. difficult to measure L because pipe is curved/pipe does not expand as expected/L is not the distance between the holes. G Difficulty with string e.g. string changes length when wet. *1 mark for each point up to a maximum of 4.*	**4**
2(f)(ii)	A Take more readings (for different values of x) and plot a graph **or** take more readings and compare k values (**not** "repeat readings" on its own). B Clamp rule/use a plumb line. C Increase length of rod/pipe. D Use a stirrer for the water/clamp thermometer/thermostatically controlled water bath. E Measure T_0 just before water is added. F Use tape measure/string and ruler **or** make L the distance between the holes. G Use named waterproof material e.g. nylon string/plastic/metal wire. *1 mark for each point up to a maximum of 4.*	**4**