Problem 2: Mechanical Blackbox

I. Determination of CM (1.0 points) *marks are either full or zero

Physical concepts/Understanding (0.4 points)	
Points	**Concepts/Details**
0.4	**P1*** Method for CM measurement (schematic drawing) is scientifically reasonable: e.g. hanging the cylinder with a thread loop, hanging with strings at ends, placing at edge of table or moving balance points together until they meet.
Experimental skills and Analysis (0.2 points)	
0.2	**E1*** >=3 measurements
Accuracy and uncertainties (0.4 points) (penalty for unsuitable sig. figs. (-0.1) and missing units (-0.1))	
0.2	**A1*** Position of centre of mass 17.6 – 18.0 cm (from light end), 12.0-12.4 cm (from heavy end)
0.2	**A2** Error estimate $\leq 0.3\,\text{cm}$ from statistical error (0.2), 0.1-0.2 cm from single measurement error (0.1)

II: Determination of other parameters (9.0 points) *marks are either full or zero

Points	Concepts/Details
Physical concepts/Understanding (2.2 points)	
0.4	**P2*** Obtain expression for the period/frequency: e.g. using formula for simple harmonic motion, solving differential equation etc.
1.0	**P3*** Form a straight line equation that leads to a graph (e.g. T^2R vs. R^2 or T^2/R vs. $1/R^2$) to extract relevant parameters.
0.4	**P4*** $I_{CM} = \frac{1}{3}M\left(\frac{L}{2}\right)^2 + M\left(x_{CM} - \frac{L}{2}\right)^2 + m\left(z - x_{CM}\right)^2$
0.4	**P5*** $x_{CM} = \dfrac{mz + M\frac{L}{2}}{m+M}$
Experimental skills and Data analysis (3.7 points)	
0.6	**E2** Table: measurements T (0.2), R (0.2) and units (0.2)
1.0	**E3** Graph: appropriate scale to cover good area of the graph paper (area enclosing data points plotted covers at least half of graph paper area) (0.3)*, correct plotting of data (all correct (0.4)/some incorrect (0.2)/all wrong (0)) and units (0.3)

Points	Concepts/Details
1.3	**E4** Quality of data: For each measurement: >=10 oscillations (0.5), >=7 oscillations (0.3), others (0) -Number of measurement at each pivoting position: >=3 meas. (0.3), 2 meas. (0.1) , 1 meas. (0 pt) -Number of pivoting positions: >= 10 pos. (0.5), >= 8 pos. (0.4) , >= 5 pos. (0.3), < 5 (0).
0.4	**E5** Form two equations between *z* and *M/m*. (0.2 each)
0.4	**E6** Use these equations to find z (0.2) and *M/m* (0.2).
Accuracy and uncertainties (3.1 points) **(penalty for unsuitable sig. figs. (-0.1) and missing units (-0.1))**	
0.6	**A3** Obtain a correct value of *g* from the slope of the graph. The value of g 968 – 988 (0.6) 958 – 967 or 989 – 998 (0.3) cm/s^2
0.3	**A4** Equation for finding error of *g* (0.2), acceptable method of finding the precursor error(s) (0.1).
0.6	**A5** Obtain a correct value of *z* The value of z 25.9 – 26.2 (0.6) 25.5 – 25.8 or 26.3 – 26.6 (0.3) cm
0.6	**A6** Obtain a correct value of M/m The value of M/m 2.6 – 2.8 (0.6) 2.5 – 2.59 or 2.81 – 2.9 (0.3)
0.6	**A7** Equation for finding error of *z* (0.2), acceptable method of finding the precursor error(s) (0.1). Equation for finding error of (*M/m*) (0.2), acceptable method of finding the precursor error(s) (0.1).
0.4	**A8*** $\Delta z \le 0.4\,\text{cm}$ or $\Delta(M/m) \le 0.15$