Annotations used in marking
BOD - Benefit of doubt
ECF - Error carried forward
POT - Powers of ten error
TE - Transfer error
CE - Calculation error
XP - Wrong physics
ENG - Generally bad english, phrasing and expression
PP - Poor presentation of answers
Note: For POT and TE, we can award the M mark, not the A mark.

Question	
Q1	
(a)(i)	Value of L to the nearest mm in the range of 98.5−99.5 cm with unit
(b)(i)	Measurement of θ to the nearest degree with unit.
(b)(ii)	Percentage uncertainty in θ based on absolute uncertainty in the range of 2°−5°. Absolute uncertainty to 1 s.f. Correct method of calculation to obtain percentage uncertainty. Percentage uncertainty to 1 or 2 s.f.
(c)(i)	C calculated correctly with appropriate units. Show working with correct substitution of values.
(c)(ii)	Plot straight line graph of sin θ against $(\frac{n^2}{2} - n)$.
	Gradient = C
(d)	Value of k correctly calculated and with appropriate units k in the range of 15−30 N m^{-1}
(e)	Compare k from (d) together to uncertainty of θ with the actual value of k
	Correct conclustion based on result

[Total: 9 marks]

Q2	
(a)(i)	Value of *x* in the range of 48.0−52.0 cm with unit and correct decimal place.
(b)	Six sets of readings of *x* and *V* Range >= 35 cm
	Correct column headings Each column heading must contain a quantity, a unit and a separating mark where appropriate
	Correct decimal place of raw values for *x* and *V*.
	Correct significant figures for the calculated values of $\frac{1}{V}$ and correct calculation of $\frac{1}{V}$.
(c)	(Graph) Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed. Scales must be chosen so that plotted points occupy at least half the graph grid in both the *x* and *y* directions. Axes must be labelled with the quantity which is being plotted.
	(Graph) All observations to be plotted. Work to an accuracy of at least half a small square.
	(Graph) Line of best fit – even distribution of points on both sides of the line. Anomalous point should be circled and labelled on the graph. (minimum must circle it)
	Points used to calculate the gradient must be greater than half the length of the drawn line. Read-offs must be accurate to half a small square and indicated on graph. Calculation of gradient must be accurate.
	y-intercept read off accurately with correct precision, OR, calculated accurately from y = mx + c using one point on the line. Check for sf if calculated (ecf for wrong gradient) Check for dp if read off graph

	Determine *k* by associating $\frac{1}{kE}$ = gradient and $\frac{1}{E}$ = y-intercept. Solve for *k*. Check for correct calculation. Check for units of *k.*
(d)	For a plot of 1/V against x, when *E* is larger, the gradient is smaller and the vertical intercept is smaller.

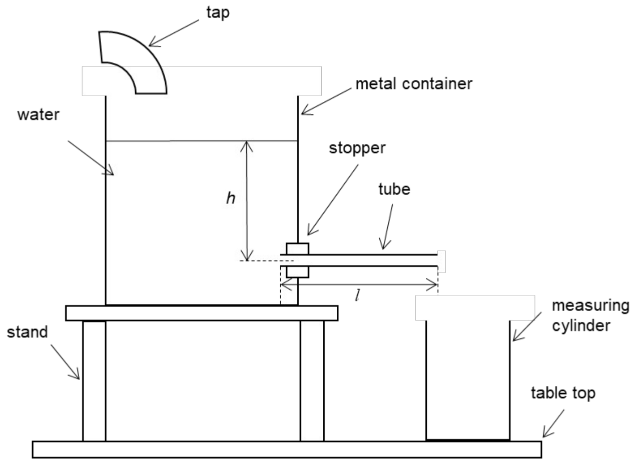
[Total: 13 marks]

Q3	
(a)(i)	Repeated readings for N oscillations. Time taken for N oscillations, t ≥ 20.00 s $T = \frac{t}{N}$ Value of *T* in the range 0.50 to 1.00 s.
(a)(ii)	Correct calculation of *k*.
(b)	Value of *y* to nearest 0.001 m and in range 0.090 to 0.130 m.
(c)	Value for *H* calculated using the readings for the highest and lowest points.
	Evidence of repeated readings of *H*.
(d)	Percentage uncertainty based on absolute uncertainty of at least 0.6 cm to 4 cm. Show correct method of calculation to obtain percentage uncertainty. Answer must be given to 1 or 2 sf.
(e)	Second set of *y* and *H* recorded. *y* within 10% of half the value in **(b)**
	second *H* < first *H*
(f)(i)	The highest and lowest positions are difficult to determine since the mass is moving too fast. The readings for the highest and lowest positions are read off by the experimenter using the metre rule. Hence *H* is inaccurate.
(f)(ii)	Use a datalogger connected to a motion sensor and place the motion sensor facing the base of the mass hanger. From the graph obtained using the datalogger, determine H difference between the lowest and highest points.
(g)(i)	Both values of *c* correctly calculated. Units for *c* Given to 2 or 3 sf (depending on sf of *H* and *y*)
(g)(ii)	Follows the least sf between *H* and *y* Which quantity to follow – *H* or *y* (or both have the same sf)
(g)(iii)	(1) Find percentage difference in *k* = ($c_{larger} - c_{smaller}$) / $c_{smaller}$ x 100 %. (2) Find percentage uncertainty in *c*. Since $\frac{\Delta H}{H}$ was calculated in (d), it is assumed that $\frac{\Delta H}{H}$ is a good approximation for the uncertainty of *c*. (3) If percentage difference in *c* > percentage uncertainty in *c*, experiment results do not support the relationship. If percentage difference in *c* < percentage uncertainty in *c*, experiment results support the relationship.

(h)	**Diagram (1 m)**
	Fully labelled diagram: Card attached to the base on the mass hanger using blue tac modified from Fig. 3.1. Ensure card in centralized.
	Basic Procedure (1 m)
	Vary the diameter of the card attached. Ensure the card's diameter is equal to or larger than the base of the mass hanger.
	Measurement (1 m)
	Measure the diameter of the cards. Repeat measurement by rotating card. Use metre rule to measure the diameter.
	Analysis (1 m)
	Plot a graph of lg T vs lg d and determine if the gradient is close to 1. Otherwise not directly proportional.
(j)(i)	20.0 s ≤ t ≤ 40.0 s. Express to with correct unit and to 1 or 2 d.p with repeated reading.
(j)(ii)	Correct d.p. and column headings for t and m.
	3 sets of data including the result from (j)(i) with full range from 250g to 300g and repeated readings for t.
(j)(iii)	Based on the three sets of data shown, as m increases t decreases.

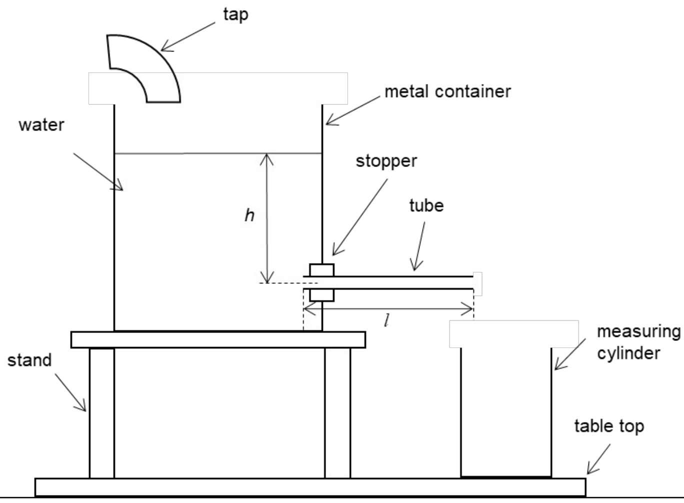
[Total: 21 marks]

4	Suggested solution



1. Setup the apparatus as shown above
2. Measure the inner diameter of the tube using a vernier calipers. Ensure only tubes with the same diameter is used for the experiment
3. Ensure the tube is horizontal by measuring the distance between 2 different points on the tube to the table top and ensuring they are the same
4. Measure the length of the tube l using a metre rule
5. Place a towel below the measuring cylinder to capture any spillage
6. Switch on the tap and let the water flow into the metal container. Adjust the flow of the water such that the height of the water in the metal container remains the same.
7. Measure the height of the water from the centre of the tube *h* using a metre rule
8. Place a measuring cylinder below the tube to collect the water. Start the stop watch at the same time.
9. Stop the stopwatch after the measuring cylinder is about three quarter full. Record down the time and read of the volume of the water collected from the measuring cylinder. Determine the flow rate *F* by dividing the volume of water collected by time
10. Repeat the experiment step 7 and 9 to get a repeated value for the flow rate.
11. By adjusting the flow of water using the tap, obtain 6 more different values of *h*. Repeat experiment step 7 to 10 to obtain the respectively flow rate. The same tube has to be used for all different *h* to ensure l remains constant
12. Using the equation $F = \frac{k\ d^4\ h^n}{l^m}$, $\ln F = \ln(\frac{k\ d^4}{l^m}) + n\ln(h)$, plot a straight line of ln *F* against ln *h* where *n* is the gradient and $\ln(\frac{k\ d^4}{l^m})$ is the vertical intercept
13. By using tubes to different length, obtain 6 more different values of l. Repeat experiment step 7 to 10 to obtain the respectively flow rate. Ensure the height of the water is the same for all different l to ensure *h* remains constant. Ensure only tubes with the same diameter as the earlier experiments are used
14. Using the equation $F = \frac{k\ d^4\ h^n}{l^m}$, $\ln F = \ln(k\ d^4\ h^n) - m\ln(l)$, plot a straight line of

	ln F against ln l where $-m$ is the gradient and $\ln F = \ln(k\ d^4\ h^n)$ is the vertical intercept

	Mark scheme	
	Diagram (1 m)	
		
	Diagram must include measuring cylinder, source of running water	**D1**
	Basic procedure (3 m)	
	Adjust the length of the tube (by using tube of different length) while keeping height constant	**B1**
	Adjust the height of the water level (by adjust the flow rate of the tap) while keeping length constant	**B1**
	Collect and measure the volume of water and the time taken for the collection and show equation F = Q / t	**B1**
	Measurement (2m)	
	Measure the length of the tube using a metre rule OR Measure the depth of the water level using a metre rule	**M1**
	Measure the flow rate using a measuring cylinder <u>and</u> stop watch	**M1**
	Control of Variables (1 m)	
	Radius of the tube must be kept constant by using tube of the same diameter	**C1**
	Analysis (2 m)	
	$F = \dfrac{k\ d^4\ h^n}{l^m}$ $\ln F = \ln(k\ d^4\ h^n) - m\ln(l)$ when varying length, Plot a straight line of $\ln F$ against $\ln(l)$ where $-m$ is the gradient and $\ln(k\ d^4\ h^n)$ is the vertical intercept	**A1**

	$F = \frac{k\, d^4\, h^n}{l^m}$ $\omega = kr^x m^y$ $\ln F = \ln(\frac{k\, d^4}{l^m}) + n\ln(h)$ when varying height of the water level, Plot a straight line of $\ln F$ against $\ln(h)$ where n is the gradient and $\ln(\frac{k\, d^4}{l^m})$ is the vertical intercept	**A1**
	Further Details (max 2 m)	
	Indicate location of metre rule inside the container when measuring height	**F1**
	Method to ensure tube is horizontal (eg, measure and ensure the distance from 2 ends of the tube to the table is the same)	**F1**
	Method to measure *h* accurately from the centre of the hole (eg, measure diameter of hole, add half of diameter to the distance from the top of the hole to the water level)	**F1**
	Repeated reading for the measurement of flow rate	**F1**
	Adjust flow of water such that flow rate of water from tap is equal to *F* in order to keep *h* constant	**F1**
	Measure the diameter of the tube using vernier callipers (to ensure the radius of the tube is the same)	**F1**
	Safety (1 m)	
	Usage of tank / sink / cloth to prevent spillage onto the table	**S1**