Question	Answer	Marks
1	**Defining the problem**	
	f is the independent variable and *Q* is the dependent variable, or vary *f* and measure *Q.*	**1**
	Keep *h* constant	**1**
	Methods of data collection	
	Labelled diagram of workable experiment including: • fan is positioned in line with the turbine so that blades of both fan and turbine overlap • base of fan on same bench as turbine • fan labelled and one other label from bench, (wind) turbine, cable, pump, pipe, liquid	**1**
	Labelled apparatus showing workable method to collect the liquid from the top of the pipe, e.g. hose / pipe / tube connected to top of pipe with the other end over a beaker / measuring cylinder below top of pipe. At least one label related to collection of liquid.	**1**
	Use of stop-watch / timer to measure time to collect liquid **or** to measure time for blades to rotate.	**1**
	Use of (top pan) balance to measure mass of liquid leaving the pipe.	**1**
	Method of Analysis	
	Plots a graph of Q against f^3 or equivalent (e.g. f^3 against Q). Do not accept logarithmic graphs.	**1**
	$C = gh \times y$-intercept (for f^3 against Q: $C = -D \times y$-intercept)	**1**
	$D = gh \times$ gradient (for f^3 against Q: $D = \frac{gh}{\text{gradient}}$)	**1**

Question	Answer		Marks
1	**Additional detail including safety considerations** Any **six** from:		**6**
	D1	Precaution with reason linked to prevent liquid spilling (on bench / floor) e.g. use of large bucket / bowl / tray to contain any spilled liquid **or** Precaution with reason linked to prevent air / dust particles in eye, e.g. use of goggles **or** Precaution with reason linked to turbine falling, e.g. clamp turbine to bench.	
	D2	Use rule to measure *h*.	
	D3	Method to determine mass of liquid, e.g. mass of beaker + liquid – mass of empty beaker **or** mass of container / pipe before – mass of container / pipe after.	
	D4	Method to determine *f*, e.g. measure time *t* for many rotations / revolutions *N* and period $T = t/N$ and $f = 1/T$ **or** measure time *t* for many rotations / revolutions *N* and $f = N/t$ **or** video rotating blades, playback frame by frame and use a time stamp to determine period *T* and $f = 1/T$.	
	D5	Mark one of the blades to assist in counting number of rotations.	
	D6	Method to vary *f*, e.g. change speed of fan / change distance between fan and blades / vary current in fan.	
	D7	Wait for steady air flow before starting timing and / or collecting liquid.	
	D8	$Q = \frac{\text{mass (of liquid)}}{\text{time (to collect liquid)}}$ **or** method and explanation to reduce uncertainty in *Q*, e.g. use large value of time or mass of liquid collected.	
	D9	Repeat measurements of *Q* for the same value of *f* **and** average *Q*.	

Question	Answer	Marks
1	D10 Relationship valid <u>if</u> a straight line is produced (not passing through the origin). Do not accept passing through the origin.	

Question	Answer	Marks
2(a)	gradient = $\frac{v}{4}$ y-intercept = $-k$	**1**
2(b)	<table><tr><th>$1/f$ / 10^{-3} Hz^{-1}</th><th>d / cm</th></tr><tr><td>0.67 or 0.667</td><td>24.7 ± 0.2</td></tr><tr><td>0.48 or 0.476</td><td>17.4 ± 0.2</td></tr><tr><td>0.36 or 0.357</td><td>12.7 ± 0.3</td></tr><tr><td>0.24 or 0.244</td><td>8.4 ± 0.3</td></tr><tr><td>0.19 or 0.192</td><td>6.6 ± 0.4</td></tr><tr><td>0.13 or 0.132</td><td>4.6 ± 0.4</td></tr></table>First mark: values of $1/f$ and d correct as shown. Second mark: uncertainties in d correct as shown.	**2**
2(c)(i)	Six points from **(b)** plotted correctly. Must be within half a small square. Diameter of points must be less than half a small square.	**1**
	Error bars in d / cm plotted correctly. All error bars to be plotted. Total length of bar must be accurate to less than half a small square and symmetrical.	**1**

Question	Answer	Marks
2(c)(ii)	Straight line of best fit drawn. Do not accept line from top plot to bottom plot. Points must be balanced. Line must pass between (0.170, 6.0) and (0.185, 6.0) **and** between (0.590, 22.0) and (0.610, 22.0)	**1**
	Worst acceptable line drawn. Steepest or shallowest possible line that passes through all the error bars. All error bars must be plotted.	**1**
2(c)(iii)	Gradient determined with clear substitution of data points into $\Delta y / \Delta x$; distance between data points must be greater than half the length of the drawn line.	**1**
	Gradient determined of worst acceptable line 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(c)(iv)	*y*-intercept determined by substitution of correct point with consistent power of ten in *m* and *x* into $y = mx + c$. Expect *y*-intercept to be negative.	**1**
	y-intercept of worst acceptable line determined by substitution into $y = mx + c$. uncertainty = *y*-intercept of line of best fit – *y*-intercept of worst acceptable line, or uncertainty = ½ (steepest worst line *y*-intercept – shallowest worst line *y*-intercept)	**1**

Question	Answer	Marks
2(d)	v determined using gradient **and** v and k given to 2 or 3 sf. $v = 4 \times \text{gradient} = 4 \times$ **(c)(iii)**	**1**
	k determined using y-intercept **and** units for v and k $k = -y\text{-intercept} = -$**(c)(iv)** Units: v: m s^{-1}, cm s^{-1} k: m, cm	**1**
	Absolute uncertainties in v and k. Δv: $\frac{\Delta\text{gradient}}{\text{gradient}} \times v$ with correct substitution **or** Δv: 4 × uncertainty in gradient **and** Δk: uncertainty in y-intercept	**1**
2(e)	f determined to a minimum of 2 significant figures from **(c)(iii)** and **(c)(iv)** OR **(d)** with correct substitution **and** correct powers of ten used for all quantities. $f = \frac{v}{4 \times (d + k)}$ **or** $f = \frac{\text{gradient}}{d - (y\text{-intercept})}$	**1**