Question	Answer	Marks
1	**Defining the problem** θ is the independent variable and v is the dependent variable, or vary θ and measure v.	**1**
	Keep d constant	**1**
	Methods of data collection Labelled diagram of workable experiment including: • sheet supported by stand / jack • light gate positioned at X • support, light gate and X labelled.	**1**
	Light gate connected to timer / datalogger.	**1**
	Measure length (L) (of card) interrupted by beam for single light gate.	**1**
	Method to measure θ, e.g. use protractor or Method to determine θ, e.g. use a rule(r) to measure two appropriate distances to use in a trigonometrical ratio	**1**
	Method of Analysis Plots a graph of v^2 on y-axis and sin θ on x-axis. **Allow** other valid graphs, e.g. sin θ against v^2 Do not accept log graphs.	**1**
	$p = \frac{\text{gradient}}{2d}$ for v^2 against sin θ or $p = \frac{1}{2d \times \text{gradient}}$ for sin θ against v^2	**1**

Question	Answer	Marks
1	$q = -\dfrac{m \times y - \text{intercept}}{2Bd}$ for v^2 against sin θ or $q = \dfrac{mp \times y - \text{intercept}}{B} = \dfrac{m \times y - \text{intercept}}{2dB \times \text{gradient}}$ for sin θ against v^2	**1**
	Additional detail including safety considerations Any six from:	**6**
	D1 Method to <u>stop</u> the trolley once the trolley passes X, e.g. place a block / stop on the bench near the end of the sheet Ignore trolley falls	
	D2 Keep *B* <u>and</u> *m* constant	
	D3 Use a rule(r) to measure *d*	
	D4 Method to keep *d* constant, e.g. mark distance *d* on the sheet or the starting position of the trolley on the sheet	
	D5 Method to measure mass of trolley (and magnet), e.g. use balance or use newton meter to measure weight and divide by *g* <u>and</u> Measure *B* using a (calibrated) Hall probe	
	D6 Additional detail on use of Hall probe, e.g. adjust probe until <u>maximum</u> value or measure *B* using Hall probe first in one direction, then in the opposite direction and average	
	D7 Determine *v* (the velocity at X) from *L* / *t* (for a single light gate)	
	D8 Additional detail on measuring θ, e.g. protractor drawn in correct position on diagram, or additional detail on determining θ, e.g. relationship between measured lengths and θ	

Question	Answer	Marks
1	D9 Relationship valid <u>if</u> a straight line is produced (not passing through the origin)	
	D10 Repeat experiment for each θ <u>and</u> average v.	

Question	Answer	Marks
2(a)	Gradient = $\frac{1}{2\pi fC}$	**1**
2(b)	$\frac{1}{R}$ / $10^{-3}\,\Omega^{-1}$ | tan θ 83 or 83.3 | 6.17 or 6.174 63 or 62.5 | 4.51 or 4.511 45 or 45.5 | 3.27 or 3.271 30 or 30.3 | 2.16 or 2.164 26 or 25.6 | 1.86 or 1.857 23 or 23.3 | 1.68 or 1.684	**1**
	Absolute uncertainties in $\frac{1}{R}$ from $\pm$ 4 to $\pm$ 1	**1**

Question	Answer	Marks
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 $\frac{1}{R}$ 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**
2(c)(ii)	Straight line of best fit drawn. Points must be balanced. Do not accept line from top plot to bottom plot. Line must pass between (33.5, 2.5) and (35.0, 2.5) and (74.0, 5.5) and (76.0, 5.5)	**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 WAL with clear substitution of data points into $\Delta y/\Delta x$; 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)	99 ± 2 (Hz)	**1**
2(e)(i)	*C* determined using gradient and *C* given to two or three significant figures. $C = \frac{1}{2\pi f \times \text{gradient}} = \frac{1}{2\pi \times \mathbf{(d)} \times \mathbf{(c)(iii)}}$	**1**
	C determined using gradient with correct SI unit and power of ten for C: F or s Ω^{-1}	**1**

Question	Answer	Marks
2(e)(ii)	Percentage uncertainty in C determined with method shown. $\%\text{uncertainty} = \left(\frac{\Delta f}{f} + \frac{\Delta\text{gradient}}{\text{gradient}}\right) \times 100$ OR Correct substitution for max/min methods $\max C = \frac{1}{2\pi \times \min f \times \text{mingradient}}$ $\min C = \frac{1}{2\pi \times \max f \times \text{maxgradient}}$	**1**
2(f)	R determined to at least two significant figures with appropriate power of ten from **(c)(iii)** OR **(d)** and **(e)(i)** with correct substitution seen. $R = \frac{\text{gradient}}{\tan\theta} = \frac{\textbf{(c)(iii)}}{0.839}$ OR $R = \frac{1}{2\pi f C \tan\theta} = \frac{1}{2\pi \times \textbf{(d)} \times \textbf{(e)(i)} \times 0.839}$	**1**
	Absolute uncertainty in R determined. Method must be consistent with determination of R and correct substitution must be seen. For R determined by using the gradient: $\Delta R = \frac{\Delta\text{gradient}}{\text{gradient}} \times R$ OR For R determined by using **(d)** and **(e)(i)**: $\Delta R = \left(\frac{\Delta f}{f} + \frac{\Delta C}{C}\right) \times R$ OR ΔR determined by max / min methods.	**1**