Q1	
(a)	Value of *w* (measured to the nearest mm) with unit and in the range 69.0 – 71.0 cm. Value of I_1 (measured to the nearest 0.1 mA) with unit.
(b)	Correct calculation of I_1I_2 with unit. Value of I_2 is smaller than value of I_1.
(c)	Four sets of readings of *w*, I_1 and I_2 and, the range of *w* is more than or equal to 30.0 cm
	Column headings: Each column heading must contain a quantity, a unit and a separating mark where appropriate. The presentation of quantity and unit must conform to accepted scientific convention, e.g. $\frac{1}{w}$ / m^{-1}, I_1I_2 /×10^{-4} A^2 .
	Significant figures: All values of $\frac{1}{w}$ must be given to the same number of s.f. as (or one more than) the number of s.f. in *w*. All values of I_1I_2 must be given to the same number of s.f. as (or one more than) the least number of s.f. in I_1 and I_2.
(d)(i)	Plotting of points: All observations in the table must be plotted on the grid. Diameter of plotted points must be $\leqslant$ half a small square. Points must be plotted to an accuracy of half a small square in both *x* and *y* directions.
	Line of best fit: There must be an even distribution of points either side of the line along the full length. Allow one anomalous point only if clearly indicated (i.e. circled or labelled). Lines must not be kinked or thicker than half a small square.
(d)(ii)	Gradient: The hypotenuse of the triangle used must be greater than half the length of the drawn line. Both read-offs must be accurate to half a small square in both the *x* and *y* directions. Method of calculation must be correct (not Δx / Δy). Gradient sign on answer line matches graph drawn. Value of *P* = candidate's gradient Unit for *P*: A^2 m
	Vertical intercept: Correct read-off from a point on the line and substituted into $y = mx + c$ or an equivalent expression. Read-off accurate to half a small square in both *x* and *y* directions. Value of *Q* = candidate's intercept Unit for *Q*: A^2
(d)(iii)	When $\frac{1}{w} = 0$, $w = \infty$. This is not possible to obtain as we only used one metre in length for the wire.

Q2	
(a)(i)	Zero error recorded. Value of D_1 (measured to the nearest 0.002 cm) with repeated readings and in the range 3.500 – 4.500 cm.
	Correct calculation of C_1 with unit.
(a)(ii)	Justification of the number of significant figures of C_1 linked to the number of s.f. in M_1 and D_1. C_1 has the same number of s.f. as (or one more than) the least number of s.f. in M_1 and D_1.
(a)(iii)	Value of t (measured to the nearest 0.1 s) with repeated readings.
(a)(iv)	Percentage uncertainty in t expressed to 1 or 2 s.f. based on an absolute uncertainty of 0.5 – 0.8 s. Correct method of calculation to obtain percentage uncertainty. percentage uncertainty in $t = \frac{\Delta t}{t} \times 100\%$
(b)(i)	Zero error recorded. Value of D_2 (measured to the nearest 0.002 cm) with repeated readings and in the range 6.000 – 8.000 cm.
	Correct calculation of C_2 with unit.
(b)(ii)	Value of t (measured to the nearest 0.1 s) with repeated readings and value of t in **(b)(ii)** is greater than value of t in **(a)(iii)**.
(c)	Two values of k calculated correctly with the correct unit. Allow 2 or 3 s.f.
(d)	Calculation of percentage difference between candidate's two k values. Valid comment consistent with the calculated values of k, testing against a criterion stated by the candidate.
(e)	Zero error recorded. Value of d (measured to the nearest 0.002 cm) with repeated readings and in the range 0.550 – 0.650 cm.
	Correct calculation of two values of a with unit. Value of a with larger N is smaller than value of a with smaller N. Allow 2 or 3 s.f.

Q3	
(a)(i)	Value of h (measured to the nearest mm) with unit and in the range 59.0 – 61.0 cm.
(a)(ii)	Value of t_1 (measured to the nearest 0.1 s). Evidence of repeated measurement of nT_1 where $nT_1 \geq 20.0$ s. T_1 is expressed to the correct s.f. with unit.
(b)(i)	Value of t_2 (measured to the nearest 0.1 s). Evidence of repeated measurement of nT_2 where $nT_2 \geq 20.0$ s. T_2 is expressed to the correct s.f. with unit.
(b)(ii)	Six sets of readings of h, n_1, t_1, n_2, t_2. Range of h is more or equal to 30 cm.
	Precision of raw values: Value of h measured to the nearest mm Value of t_1 and t_2 measured to the nearest 0.1 s. Correct precision of raw values in **(a)(i)**, **(a)(ii)** and **(b)(i)**.
	Column headings: Each column heading must contain a quantity, a unit and a separating mark where appropriate. The presentation of quantity and unit must conform to accepted scientific convention, e.g. $\frac{1}{h}$ / m^{-1}, $T_2^2 - T_1^2$ / s^2.
	Significant figures: All values of $\frac{1}{h}$ must be given to the same number of s.f. as (or one more than) the number of s.f. in h. All values of $T_2^2 - T_1^2$ must be given to the same number of s.f. as (or one more than) the number of s.f. in T_1 and T_2.
	Calculation: Correct calculation of $\frac{1}{h}$ and $T_2^2 - T_1^2$.
(c)	Linearisation: Plotting statement to linearise the equation.
	Axes: Sensible scales must be used, no awkward scales (e.g. 3:10 or fractions). Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Scales must be labelled with the quantity that is being plotted.
	Plotting of points: All observations in the table must be plotted on the grid. Diameter of plotted points must be $\leqslant$ half a small square. Points must be plotted to an accuracy of half a small square in both x and y directions.
	Line of best fit: There must be an even distribution of points either side of the line along the full length. Allow one anomalous point only if clearly indicated (i.e. circled or labelled). Lines must not be kinked or thicker than half a small square.
	Gradient: The hypotenuse of the triangle used must be greater than half the length of the drawn line. Both read-offs must be accurate to half a small square in both the x and y directions. Method of calculation must be correct (not Δx / Δy). Gradient sign on answer line matches graph drawn.
	Vertical intercept:

	Correct read-off from a point on the line and substituted into $y = mx + c$ or an equivalent expression. Read-off accurate to half a small square in both x and y directions. OR Intercept read directly from the graph, with read-off at $\frac{1}{h} = 0$, accurate to half a small square.
	Value of X = candidate's gradient and value of Y = candidate's vertical intercept. The values must not be fractions. Unit for X: s^2 m, s^2 cm or s^2 mm and unit for Y: s^2.
(d)	Value of m (measured to the nearest 0.01 g) with unit and in the range 68.0 – 78.0 g.
	Correct calculation of M with unit.
(e)	Line labelled W with steeper gradient and no change to vertical intercept.
(f)	• Set up the experiment as shown in Fig. 3.2. • Vary the mass m of the pendulum bob by using different pendulum bobs and determine T_2.
	• Keep the distance h from the centre of the pendulum bob to the centre of the metre rule constant.
	• Plot a graph of T_2 against m. If the graph is a horizontal line, T_2 is independent of m. OR • Obtain 3 or more readings. If T_2 remains the same for all 3 sets of data, T_2 is independent of m.

Question 4	
Diagram (1 m)	
Labelled diagram of workable experiment including: • bench • elastic cord • mass • retort stand • measuring tape • video camera on the ground	**D**
Basic Procedure (2 m)	
Vary the mass m by using different masses and keep the force constant of the elastic cord constant by using the same material (and diameter).	**B**
Vary the force constant of the elastic cord by using different material (of the same diameter) / different diameter of the same material and keep the mass m constant by using the same mass.	**B**
Measurement (3 m)	
Measure the mass m of the mass using an electronic balance. OR Measure the natural length L_0 of the elastic cord using a metre rule.	**M**
Method to determine force constant k of the elastic cord, e.g. hang a mass on the elastic cord and determine the extension x. k can be found using mg/x.	**M**
Method to determine maximum extension E, e.g. Use a video camera to record maximum length L with the measuring tape as the reference. E can be found using L - L_0.	**M**

Control of Variables (1 m)	
Keep the length of the elastic cord constant OR Keep the height of release of the mass constant	**C**
Analysis (2 m)	
$\lg E = p \lg m + \lg\left(Ck^q\right)$ Plot lg *E* against lg *m* and a straight line graph will be obtained and its gradient is *p*. OR $\lg E = q \lg k + \lg\left(Cm^p\right)$ Plot lg *E* against lg *k* and a straight line graph will be obtained and its gradient is *q*.	**A**
Calculate *C* using a set of values of *E*, *m* and *k* where $C = \dfrac{E}{m^p k^q}$.	**A**
Further Details (2 m)	
Release the mass from a height and record the lowest point reached in the fall.	**F**
Repeat the experiment for each value of *E* and determine average *E* to reduce random error.	**F**
Video camera shown at lowest point of fall and description of playback frame-by-frame or slow motion to determine *L*.	**F**
Conduct preliminary experiments to estimate an appropriate height to release the mass (not too low such that the fractional uncertainty for *E* is large and not too high when it hits the ground)	**F**
For knowing that diameter of the elastic cord will affect the force constant *k*.	**F**
Check that limit of proportionality is not exceeded. The length of the elastic cord will return to its natural length when the mass is removed.	**F**
Safety (1 m)	
Place a counterweight on the base of the retort stand to prevent the stand from toppling. OR Place a tray below the weight to cushion the fall in case the mass hits the floor. OR Wear googles as the mass may dislodge from the elastic cord and hit them.	**S**