

Answers

Chapter 1: AS & A Level exercise

1A

Risk: The masses may fall onto your feet/floor.

Precautions: Place cloths/box/bag under the masses so that they are caught if they fall.

Chapter 2: AS Level exercises

2A

For each answer, 1 mark is for identifying the type of error and 1 is for justification.

- a** Systematic: [1] the same error (radius of the bob) is introduced into each reading [1]
- b** Random: [1] reading the thermometer at the correct time interval/parallax errors/reading thermometer from different angle [1]
- c** Random: [1] stopping and starting the stopwatch at the exact moment; reaction time [1]
- d** Random: [1] reading the ruler from different angles/parallax [1]

2B

- a i** $\pm 0.1^{\circ}\text{C}$ [1]
 - ii** $\pm 0.01\text{ g}$ [1]
 - iii** $\pm 0.01\text{ mm}$ [1]
 - iv** $\pm 1^{\circ}$ [1]
- b** $\left(\frac{2}{100} \times 2.58\right) + 0.03 = \pm 0.08\text{ V}$

2C

- a** Reading in Figure 2.10a: 7.60 mm [1]
- b** Reading in Figure 2.10b: 4.57 cm [1]

2D

Use a top pan balance to find the mass: [1] make sure the pan is clean/tare the balance, place cube on the pan and record the mass [1] $\pm 0.1\text{ g}/\pm 0.01\text{ g}$ [1]

Calipers/ruler/micrometer (if it were a small cube) [1]

1 mark for correct description of chosen instrument:

Calipers: place the cube between the external jaws. Close slowly using the dial. Stop as soon as you feel any resistance.

Ruler: place against the edge and read the ruler looking perpendicular to the edge.

Micrometer: place the cube in the gap and tighten using the ratchet at the end. When you hear a click stop tightening.

Caliper $\pm 0.1\text{ mm}$ /ruler $\pm 1\text{ mm}$ /micrometer $\pm 0.01\text{ mm}$ [1]

2E

a Measurements:

diameter of ball using micrometer/calipers [1]

distance ball falls through using metre ruler [1]

temperature of oil using a thermometer [1]

time for ball to fall using a stopwatch [1]

b Maximum 3 marks; any 3 from:

reaction time

knowing when to start and stop watch

difficulty of taking diameter measurements

parallax errors reading thermometer/ruler

changing temperature of oil during the experiment

oil not all being at the same temperature

c Number of measurements 6–9 [1]

range – suggestion $10^{\circ}\text{C} \leq \text{to} \geq 60^{\circ}\text{C}$ [1]

repeats – at each temperature (at least 2) [1]

diameter of ball (at least 2) [1]

Chapter 3: AS Level exercises

3A

Each column has heading with quantity and units. [1]

Headings for repeats and mean value; [1] order of columns not important; example shown.

V/V or Potential difference/V			I/A or Current/A			R/ Ω or Resistance/ Ω
1	2	Mean	1	2	Mean	

3B

a Each column has the correct heading with quantity and units; [1] units for $1/s^2$ correct. [1]

d/mm or diameter/mm	V/V or Potential difference/V	I/A or Current/A	R/ Ω or Resistance/ Ω	$1/d^2 / \text{mm}^{-2}$

b The correct table is shown below.

Add units where they are missing [1]

Correct precision in raw data [1]

Correct number of significant figures in values for k (2 s.f. or 3 s.f. at most as x is only known to 2 s.f.) [1]

BUT must be consistent; if one is given to 2 s.f. then all should be given to 2 s.f. in this table.

m/g	F/N	x/cm	k/Nm^{-1}
100	0.981	1.7	58 or 57.7
200	1.962	3.6	55 or 54.5
300	2.943	6.0	49 or 49.1
400	3.924	7.7	51 or 51.0

3C

Sensible scales chosen [1]

Plotted points must occupy at least half the grid in both the x - and y -direction [1]

Both axes must be labelled with quantity and units [1]

Points plotted correctly [1]

Line of best fit drawn with an even distribution of points above and below the line [1]

Chapter 4: AS Level exercises**4A**

a Gradient is A [1] y -intercept is B [1]

b Gradient is A [1] y -intercept is B [1]

c Gradient is $2a$ [1] y -intercept is u^2 [1]

d Gradient is ρ/A [1] y -intercept is 0 [1]

e Gradient is e/h [1] y -intercept is ϕ/h [1]

4B

a Large triangle drawn (hypotenuse at least half as long as line) [1]

Gradient calculated = 4.9 ± 0.1 [1]

y -intercept calculated using value of gradient and pair of coordinates [1]

$$c = y - mx = 16 \pm 6$$

b i Large triangle drawn (hypotenuse at least half as long as line) [1]

Gradient calculated = 3.0 ± 0.1 [1]

y -intercept calculated using value of gradient and pair of coordinates [1]

$$c = y - mx = -0$$

OR by extrapolating trendline

y -intercept = -1.4 ± 0.9 [must be a negative sign]

ii $A = 3.0 \pm 0.1$ and $B = -1.4 \pm 0.9$ [1]

Units of A Ω A (V) [1] Units of B Ω [1]

4C

Mean diameter = 0.26 [1] (Diameter must be quoted to 2 decimal places)

Absolute uncertainty = $(0.30 \text{ mm} - 0.22 \text{ mm})/2 = \pm 0.04 \text{ mm}$ [1]

4D

a Current = $2.4 + 5.5 = 7.9 \text{ A}$ [1]

Absolute uncertainty = $0.1 + 0.2 = 0.3 \text{ A}$ [1]

Current = $7.9 \pm 0.3 \text{ A}$

b $\rho = \frac{RA}{l} = \frac{20 \times 3.1 \times 10^{-4}}{0.06} = 0.103 \Omega \text{ m}$ [1]

Total percentage uncertainty = $0.5 + 12 + 1.7 = 14.2\%$ [1]

Absolute uncertainty = $(14.2/100) \times 0.103 = 0.01 \Omega \text{ m}$ [1]

$\rho = 0.10 \pm 0.01 \Omega \text{ m}$ [1] ρ must be quoted to 2 decimal places.

c $R = \frac{V}{I} = \frac{5.25}{0.21} = 25 \Omega$ [1]

% uncertainty in p.d. = $(0.07/5.25) \times 100 = 1.3\%$

% uncertainty in $I = (0.02/0.21) \times 100 = 9.5\%$ [1]

Total % uncertainty = $1.3 + 9.5 = 10.8\%$ [1]

Absolute uncertainty = $(10.8/100) \times 25 = 2.7 = 3 \Omega$ [1]

d $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \left(\frac{2.5}{2}\right)^3 = 8.18 \text{ mm}^3$ [1]

% uncertainty in $d = (0.01/2.5) \times 100 = 0.4\%$ [1]

% uncertainty in $V = 3 \times 0.4 = 1.2\%$ [1]

Absolute uncertainty = $1.2/100 \times 8.18 = 0.1 \text{ mm}^3$ [1]

$V = 8.2 \pm 0.1 \text{ mm}^3$ [1] Volume must be quoted to 1 decimal place

e $g = \frac{2s}{t^2} = \frac{2 \times 5}{0.9^2} = 12.3 \text{ ms}^{-2}$ [1]

% uncertainty in $s = (0.1/5) \times 100 = 2.0\%$

% uncertainty in $t = (0.2/0.9) \times 100 = 22.2\%$ [1]

Combined uncertainty = $2 + (2 \times 22.2) = 46.4\%$ [1]

Absolute uncertainty = $(46.4/100) \times 12.3 = 6$ [1]

$g = 12 \pm 6 \text{ ms}^{-2}$ [1] must be to nearest whole number

4E

a i $\rho = \frac{RA}{l} = \frac{4.8 \times 2.04 \times 10^{-7}}{0.8} = 1.22 \times 10^{-6} \Omega \text{ m}$ [1]

ii % uncertainty in $R = (0.1/4.8) \times 100 = 2.1\%$

% uncertainty in $l = (0.001/0.800) \times 100 = 0.13\%$ [1]

Combined uncertainty = $4 + 2.1 + 0.13 = 6.2\%$ [1]

iii Percentage difference = $[(1.22 \times 10^{-6} - 1.1 \times 10^{-6})/1.1 \times 10^{-6}] \times 100\% = 10.9\%$ [1]

The percentage difference is greater than the experimental uncertainty. Therefore the data does not support this. [1]

4F

a Limitations: Maximum of 2 from:

- The pendulum does not always swing along the ruler.
- The amplitudes may be too close together to judge different readings from the marks.
- It is difficult to judge the maximum amplitude of the pendulum as the pendulum is always moving/moving too quickly.

b Improvements: Maximum of 2 from:

- Increase the size of the cone on the pendulum to make the difference in amplitude greater.
- Increase the length of the pendulum so that the period of oscillation is greater.
- Film the pendulum from above with the ruler in view so that the amplitude measurements can be made using the playback.

Chapter 5: AS Level practice questions

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- 1 a** Value of x between 45.0 and 55.0 cm [1]

(Read the scale of the metre ruler with your eye directly over it (to avoid parallax error).

Make sure P is connected at 0.0 cm and read the length to the middle of the crocodile clip A).

- b** Value of y less than x [1]

- c** Six sets of readings for x and y (showing as x increases y increases) [5]

Values of x range from 20.0 cm or less to 80.0 cm or more [1]

All x and y values should be written to 1 decimal place. [1]

The headings for $1/x$ and $1/y$ should be inserted e.g. $1/x/\text{cm}^{-1}$. [1]

Values of $1/y$ calculated correctly. [1]

Values of $1/y$ written to 3 or 4 s.f. maximum. [1]

- d i** For 1 mark:

- sensible scales chosen
- plotted points must occupy at least half the grid in both the x and y directions
- both axes must be labelled with quantity and units.

For 1 mark:

- points plotted correctly
- using sharp pencil and a cross
- all results must be plotted.

For 1 mark:

- graph should show a straight line with a positive gradient and a positive intercept on the y -axis
- it should be possible to plot a straight line through the points and for the results to be precise (close to the line of best fit).

- ii** Line of best fit drawn with an even distribution of points above and below the line. [1]

- iii** Large triangle drawn with the hypotenuse longer than half the line of best fit.

$$\text{Gradient} = \frac{\Delta y}{\Delta x}$$

$$\text{Sample calculation:} = \frac{0.156}{0.04} = 3.9 \quad [1]$$

Value read from the graph at the point where $x = 0$.

y -intercept = -0.009 (must be a negative sign) [1]

(or values read from the graph and substituted into $y = mx + c$ [1]

(must be a point from the line of best fit and not the table).

$y = 0.108$ and $x = 0.03$

$$0.108 = (3.9 \times 0.03) + c$$

$$c = -0.009 \quad [1])$$

- e** Value of a = gradient (from sample data = 3.9)

and value of b = y -intercept [1]

Gradient no unit and y -intercept unit same as the y -axis [1]

e.g. -0.009 cm^{-1}

2 a i Value of C given to the nearest mm e.g. 25.0 cm. [1]

ii Value of T recorded (will be between 0.5 s and 1.5 s). [1]

The answer should show at least one repeat measurement of multiple oscillations to calculate T . At least 5 oscillations. [1]

b Data collected if doing practical or description of how to collect if using the sample results. Mark your descriptions based on the mark scheme for data collected for **ai** and **bii**.

- Collected 6 sets of data. [4] If only 5 sets of data, this is [3].
- Suitable range of C (at least 18 cm between highest and lowest values). [1]
- All column headings with suitable unit C/cm , T/s , $\frac{1}{\sqrt{C}}/\text{cm}^{-1/2}$, $\frac{1}{T}/\text{s}^{-1}$. [1]
- All raw values of T and C given to same number of decimal places e.g. T to 0.1 s or 0.01 s, C to 0.1 cm. [1]
- Values of $\frac{1}{\sqrt{C}}$ calculated correctly. [1]
- Values of $\frac{1}{\sqrt{C}}$ given to the same number of significant figures or 1 more as C

e.g. if $C = 15.0$, then $\frac{1}{\sqrt{C}} = 0.258$ or $= 0.2582$ [1]

c i For 1 mark:

- sensible scales chosen
- plotted points must occupy at least half the grid in both the x and y directions
- both axes must be labelled with quantity and units.

For 1 mark:

- points plotted correctly
- using sharp pencil and a cross
- all results must be plotted.

For 1 mark:

- graph should show a straight line with a positive gradient and a positive intercept on the y -axis
- it should be possible to plot a straight line through the points and for the results to be precise (close to the line of best fit).

ii For 1 mark:

- line of best fit drawn with an even distribution of points above and below the line
- allow one anomalous point not included in the line of best fit – but only if it is circled.

iii For 1 mark:

- large triangle drawn with the hypotenuse longer than half the line of best fit
- gradient calculated using $= \frac{\Delta y}{\Delta x}$ and has a positive gradient.

(For sample data, gradient = 5.0)

For 1 mark:

- Value read from the graph at the point $x = 0$
- (For sample data, y -intercept = 0.140
- or pair of values read from the line of best fit and using gradient these values are substituted into equation for a straight line graph ($y = mx + c$)
- Equation rearranged to find c .

d Value of a equal to gradient and value of b equal to the y -intercept. [1]

Units for a (gradient) = $\text{cm}^{1/2} \text{s}^{-1}$ and for b (y -intercept) = s^{-1} [1]

3 a Value of x given to the nearest mm and approximately equal to 40.0 cm, e.g. 39.5 cm [1]

b Value of θ recorded in the range 60–100° [1]

c There are 10 marks available for this section

Six marks for the data collected:

- Six or more pairs of data for θ with changing x . [5] If you have 5 pairs this mark decreases to [4]. If help is needed from the teacher this also reduces the mark. If you are genuinely stuck and cannot work out what to do it is better to ask for help and lose marks here.
- A suitable range for values of x e.g. at least 20 cm between maximum and minimum. [1]

Four marks for the presentation of the data:

- Correct column headings: x/cm , $\theta/^\circ$, $\cos \theta$ (no unit) [1]
- All values of x and θ given to nearest mm and nearest degree, respectively. [1]
- Values of $\cos \theta$ correctly calculated. [1]
- Values of $\cos \theta$ given to the same number of significant figures as the corresponding value of θ (or 1 more).
e.g. $\theta = 45^\circ$, $\cos 45^\circ = 0.71$ or 0.707 , $\theta = 110^\circ$ [1]

d i There are 3 marks for plotting the graph:

- Scales must be sensible so that you can easily identify points (e.g. intervals of 1, 2, 5, 10)/the plotted points must occupy at least half the graph in both the x and y directions/scales must be labelled with the quantity and the unit. [1]
- Points plotted accurately/clear crosses or circled dots/diameter of plots must be within half a small square. [1]
- Trend shows straight line graph with y -intercept/points are close to line of best fit. [1]

ii Line of best fit drawn with a ruler and with an even distribution of points above and below the line. [1]

iii Gradient found [1] to gain the point:

- A large triangle needs to be drawn whose hypotenuse is at least half the length of the line of best fit/measurements of Δy and Δx must be accurate/gradient calculated using $= \frac{\Delta y}{\Delta x}$ /same sign as your graph.
- y -intercept [1] to gain the point:
The value of the y -intercept when $x = 0$ read directly from the graph OR for a pair of x and y coordinates taken from the line of best fit and substituted into the equation $y = mx + c$. Equation rearranged to find c using value of gradient as m .

e Value of $a =$ gradient, value of $b = y$ -intercept [1]

Unit of $a = \text{cm}^{-1}$ and b has no units [1]

4 a i Value in the range 0.50 s to 1.00 s [1]

(Time at least 5 oscillations twice to find the time, T . Use a pointer placed at the centre of the oscillation to identify start of each oscillation.)

ii Correct calculation of k using value of T (e.g. from sample data $k = 25 \text{ N m}^{-1}$) [1]

b Value of y to the nearest mm and within the range 0.050 m to 0.150 m [1]

(Use a 30 cm ruler to measure the height, y . Make sure to take readings at eye level.)

c Value of H [1]

Evidence of repeats [1]

(Use a fixed metre ruler to measure the distance, H . Release the mass and mark with a pen roughly where the highest and lowest points are. Repeat and this time focus your attention on the marks to take a more accurate reading. Repeat.)

- d** Uncertainty = ± 5 mm [range of 4 to 8 mm] (acceptable to use half of the range from repeats but value cannot be 0)

Percentage uncertainty calculated correctly, e.g. using 5 mm = $[0.005/0.235] \times 100 = 2.1\%$ [1]

- e** Second values for y and H [1]

Second H less than first value of H [1]

- f i** Correct values given to 3 or more significant figures [1]

Using sample data: Rearrange equation: $c = H/\sqrt{y}$

First value of $c = 0.743$

Second value of $c = 0.805$

- ii** Both H and y known to 3 significant figures [1]

- iii** Statement with reason, e.g. using sample data

Calculate percentage difference = 8.3%/10%/8.0%

e.g. no, results are not consistent as percentage difference is 8.3%/10%/8.0%

and percentage uncertainty in H is 2.1%

OR

total percentage uncertainty = $2.1 + \frac{1}{2} \times \% \text{ uncertainty in } y$ (5%)

= 4.6% [1]

- g** Correct value of g calculated, e.g. value of $g = 8.6$ and unit N kg^{-1} [1]

- h i** Any four from:

- Need a greater range of results/more than two for a firm conclusion.
- Difficult to measure the maximum displacement/amplitude of the oscillation as it is moving.
- With oscillations the maximum displacement/amplitude is decreasing.
- Difficult to measure y as it is from the hanger to the centre of two masses not stuck together.
- Difficult to lift the masses to the same height each time.
- When trying to take two measurements for H it is hard to have eye level with the reading.
- The mass may swing from side to side as well as vertically.

- ii** Any four from:

- Take more readings and graph H versus $\sqrt{y}$ to determine c .
- Take more readings and graph T^2 versus M to calculate k .
- Clamp a ruler behind the spring to get accurate measurements of H .
- Restrict movement to vertical by carrying out in a clear plastic tube.
- Use a motion sensor placed below the mass to get H .
- Use video motion and play back to measure H .

- 5 a** Value given to the nearest mm [1]

(Use calipers or ruler to measure h . Repeat along the length and find mean value.)

- b** Value for weight given to the nearest 0.1 N [1]

(Suspend string from a hook so newton meter is hanging vertically down. Read value at eye level.)

- c i** Evidence that more than one measurement of diameter has been made and then used to find the radius [1]

(Use calipers or ruler to measure the diameter. Repeat the reading and find mean diameter.)

ii Correct calculation of α [1]

using sample data $\sin \alpha = (22 - 9)/22$

$\alpha = 36$ (or 40 to 1 s.f.)

iii Either 1 or 2 s.f. as h is known to only 1 s.f. which limits value. [1]

d Values of F given to the nearest 0.1 N with the unit [1]

Evidence of repeat measurements needed. [1]

(Gently pull the newton meter and ensure it is parallel. Read the value at eye level and repeat.

Calculate the mean value of F .)

e Uncertainty in F allow 0.2 to 0.4 N and % uncertainty correctly calculated [1]

For sample data $= (0.2/2.7) \times 100 = 7.4\%$

f Values of W , r and F taken for the 50 g masses. [1]

Second value of F is lower than first [1]

Using sample data, new $\alpha = 30$

g i Two values of k calculated correctly [1]

Using sample data

First value of $k = [2.7 \times \tan 36]/2.0 = 0.98$

Second value of $k = [1.7 \times \tan 30]/1.0 = 0.98$

ii Valid comment about whether data supports the relationship [1]

e.g. for sample data: Values are identical and therefore support the relationship (in reality this would not happen – find the percentage difference between values of k and compare to the overall percentage uncertainty of the experiment or to your % uncertainty for part e).

h i Any four from:

- Only two readings taken which is not enough to draw a valid conclusion.
- Percentage uncertainty in h is large as the height is small.
- It is hard to measure the diameter of the masses as they are not completely circular/have indent/edges not defined.
- It is hard to judge the minimum force needed to move the masses as the meter sprang to zero when the masses started to move.
- It is difficult to maintain a horizontal force that is also not at an angle when pulling the masses.
- There is a large percentage uncertainty in F as values of F are small.

ii Any four from:

- Take a greater range of readings with different diameter masses and plot a graph.
- Use calipers or micrometer to measure h .
- Place the masses between set squares to more accurately measure the diameter.
- Video the motion with a newton meter in view to read the force required to start the movement/measure using a force sensor and data logger.
- Use a string and pulley on a clamp system to provide the horizontal pulling force.
- Use a newton meter with better resolution e.g. 0–5 N.

6 a i $d = 11.0 \pm 0.4$ cm [1] value quoted to nearest mm

(using equipment specified in confidential instructions)

More than one reading [1]

- ii A calculated correctly e.g. $d = 11.0 \text{ cm}$
 $A = (\pi \times 11^2)/4 = 95.0 \text{ cm}^2$ or 95.04 cm^2 [1]
- iii d is known to 3 s.f. therefore A can be quoted to 3 (or 4) significant figures. [1]
- b i** Value of t between 0.5 s and 1.0 s quoted to either nearest 0.1 s or 0.01 s [1]
 Evidence of repeat readings of t [1]
- ii Uncertainty in $t \pm 0.2 \text{ s}$ (to 0.5 s)
 Can use repeat readings to determine uncertainty (uncertainty = $\frac{1}{2}$ range) but working must be there.
 % uncertainty correctly calculated e.g. if reading $0.6 \pm 0.2 \text{ s}$ then
 % uncertainty = $(0.2/0.6) \times 100 = 33\%$
- iii Mass in the range 2.0–10.0 g quoted to nearest 0.1 g or 0.01 g depending on top pan balance available. [1]
- c i** $d = 18.0 \pm 0.4 \text{ cm}$ value quoted to nearest mm
 A correctly calculated, e.g. for $d = 18$, $A = 254 \text{ cm}^2$ (could be quoted to 4 s.f.). [1]
- ii New value of t greater than first; mass greater than first [1]
- d i** Two values of k correctly calculated:
 $k = \frac{mA}{t}$ [1]
- ii Statement + justification. For example, find the percentage difference between your two values of k then compare this to the percentage uncertainty in the whole experiment or with uncertainty in t [bii]. [1]
- e i** Any four from:
- Two readings are not enough to draw a valid conclusion (don't simply say not enough).
 - It is hard to judge same release height due to thickness of papers/having head at eye level with reading.
 - It is hard to start the stopwatch at the same time as releasing the filter paper.
 - The filter paper does not always fall vertically/hits the ruler/the filter papers separate as they fall.
 - It is hard to judge when to stop the stopwatch as had to move head to remain level with paper.
 - The measured time is small so there is a large percentage uncertainty in t .
- ii Any four from:
- Take more readings and plot a graph/take more readings with different diameter paper and compare values of k .
 - Have a pointer at the release height – such as set square attached to the ruler/a bar at the top of the ruler.
 - Film the fall of the paper with a stopwatch in view and measure times from a play back/by using the time from the time frames of the film.
 - Use more filter papers so they are heavier and less likely to drift/stick the filter papers together with tape or glue.
 - Drop from a greater height to increase the measured time.

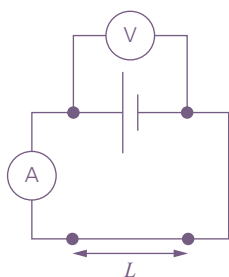
Chapter 6: A Level exercises

6A

- a** Independent variable is the diameter, d , [1] and the dependent variable is the resistance, R [1]. The control variables are the length, L , and the resistivity, ρ (or the material the wire is made from) [both needed for 1 mark] (π is a constant, it is NOT a control variable).
- b** Independent variable is the length, L , of the wire [1] and the dependent variable is the extension, x . [1]
Control variables are the mass, m , suspended from the wire, cross-sectional area [or diameter] of the wire and the Young modulus of the wire (or the material wire made from). [All three needed for 1 mark.]

6B

Circuit diagram showing a series circuit with metal wire, ammeter and power supply (circuit symbols correct).



Voltmeter connected in parallel across either wire or the power supply. Allow use of ohmmeter but no power supply needed. [1]

A diagram is essential but the remaining marks are gained for each one of these statements up to a maximum of seven:

- Measure the diameter of the wire using a micrometer. [1]
- Measure along the length at different orientations and find an average. [1]
- Connect the wire to the circuit using crocodile clips. Measure the length, L , using a ruler [1]
- from the middle of one crocodile clip to the middle of the next. [1]
- Use the same type of wire in each experiment so the resistivity is constant. [1]
- Switch on the circuit and record the readings on the voltmeter and ammeter. [1]
- Switch off and on and repeat to find mean values of voltage and current. [1]
- Repeat the experiment with a different diameter wire. [1]
- Calculate the resistance using $R = V/I$. [1]

6C

Time period = $2.0 \text{ cm} \times 10 \times 10^{-3} = 0.02 \text{ s}$ [1] (20 ms)

Frequency = $f = \frac{1}{T} = 50 \text{ Hz}$ [1]

Peak voltage = $0.7 \text{ cm} \times 5.0 \text{ V cm}^{-1} = 3.5 \text{ V}$ [1]

6D

Position a metre ruler so the scale is clearly visible from above/side. [1]

Place the camera directly above/in front of the maximum amplitude. [1]

Film the oscillations and play back the film. Pause and measure the maximum amplitude from the film. [1]

6E

- a** Plot a graph with T^2 on the y -axis and l on the x -axis (or T on the y -axis and $\sqrt{l}$ on the x -axis) [1]

It will be a straight-line graph through the origin (for both) [1]

$$g = \frac{4\pi^2}{\text{gradient}} \left(\text{or } g = \frac{4\pi^2}{\text{gradient}^2} \right) [1]$$

- b** Plot a graph with V on the y -axis and f on the x -axis [1]

It will be a straight-line graph with a y -intercept [1]

$$h = \text{gradient} \times e [1]$$

$$\phi = -y\text{-intercept} \times e [1]$$

6F

Need precaution and the reason for maximum marks.

Do not exceed 25 V as this is the rated voltage [1]

to prevent capacitor break down/explosion. [1]

OR

Connect the capacitor correctly with the positive side to positive terminal of power supply [1]

to prevent capacitor break down/explosion. [1]

Chapter 7: A Level exercises**7A**

- a** Plot a graph with v^2 on the y -axis and d on the x -axis. [1]

It should be a straight-line graph through the origin. [1]

The gradient is g . [1]

(It is not sensible to plot a log-log graph as you know the power.)

- b** Plot a graph with $\ln I$ on the y -axis and t on the x -axis. [1]

It should be a straight-line graph with a y -intercept. [1]

$$C = -1/[R \times \text{gradient}] [1] \text{ (since the gradient} = -1/CR)$$

$$y\text{-intercept} = \ln I_0$$

$$I_0 = e^{y\text{ intercept}} [1]$$

- c** Plot a graph with $\log T$ on the y -axis and $\log r$ on the x -axis. [1]

Straight line graph with y -intercept [1]

$$\text{Gradient} = n [1]$$

$$\text{The } y\text{-intercept} = \log k$$

$$\text{Therefore } k = 10^{y\text{ intercept}} [1]$$

7B

- a** $\ln(V/V) [1] = 2.35$ (or 2.351) [1]

- b** $T^2x = 1.5$ (or 1.49) [1] $\text{s}^2 \text{m}$ [1]

- c** $\log(m/g) [1] = -0.28$ (or -0.284) [1]

7C

- a i** Fractional uncertainty = $\frac{0.4}{22.8} = 0.018$ [1]
 Percentage uncertainty = $\frac{0.4}{22.8} \times 100 = 1.8\%$ [1]
- ii** Fractional uncertainty = $\frac{8}{250} = 0.032$ [1]
 Percentage uncertainty = $\frac{8}{250} \times 100 = 3.2\%$ [1]
- b i** Absolute uncertainty = $\frac{5}{100} \times 25.67 = 1.28 \text{ W}$ [1]
 Power = $26 \pm 1 \text{ W}$
- ii** Absolute uncertainty = $0.025 \times 15.29 = 0.382 \text{ m s}^{-2}$ [1]
 Acceleration = $15.3 \pm 0.4 \text{ m s}^{-2}$ [1]

7D

- a** Extension = $12.0 - 9.5 = 2.5 \text{ cm}$ [1]
 Uncertainty = $0.4 + 0.2 = 0.6 \text{ cm}$ [1]
 Extension = $2.5 \pm 0.6 \text{ cm}$
- b** $P = I^2 R = 2.4^2 \times 110 = 633.6 \text{ W}$
 % uncertainty in $I = (0.2/2.4) \times 100 = 8.3\%$ [1]
 % uncertainty in $P = (2 \times 8.3) + 5 = 22\%$ [1]
 Absolute uncertainty = $(22/100) \times 633.6 = \pm 139 \text{ W}$ [1]
 $P = 600 \pm 100 \text{ W}$ [1]

c i

Mass/g	Time for 10 oscillations/s			Time for 1 oscillation/s	log (T/s)	log (m/g)
	1	2	Mean			
$100 \pm 5\%$	2.5	3.3	2.9 ± 0.4 [1]	0.29 ± 0.04 [1]	-0.538 ± 0.056 [1]	2.00 ± 0.021 [1]

Logs can be written to 2 or 3 decimal points. Value for uncertainties calculated using $\log_{\max} - \log_{\text{quantity}}$.

ii

T/ms	$\frac{1}{T} / \text{s}^{-1}$
4.2 ± 0.2	238 [1] ± 11 [1]

Check the units carefully. Uncertainty derived using $T_{\max} - T_{\text{value}}$.

iii

$X_1 / \text{W m}^{-2}$	$\frac{X_1}{X_0}$
24.8 ± 0.2	1.63 ± 0.037

Value ± 0.03 to 0.04

7E

- a i** Data points chosen at least half the length of the line apart. [1]
- Gradient of line of best fit e.g. = $\frac{[1.23 - 1.40]}{[0.67 - 0.27]} = -0.425$ (must have negative sign) [1]
- Gradient of line of worst fit = $\frac{[1.24 - 1.40]}{[0.67 - 0.25]} = -0.38$ [1]

Absolute uncertainty in gradient = difference between gradients

$$\text{Absolute uncertainty in gradient} = 0.425 - 0.38 = 0.045$$

Gradient = -0.43 ± 0.05 [absolute uncertainty quoted to 1 s.f. and final answer consistent with absolute uncertainty]. [1]

- ii y-intercept line of best fit:

$$y = mx + c$$

$$\text{Using } m = -0.43, y = 1.4, x = 0.27$$

$$1.4 = (-0.43 \times 0.27) + c$$

$$c = 1.52 \text{ [1]}$$

y-intercept line of worst fit:

$$y = mx + c$$

$$\text{Using } m = -0.38, y = 1.40, x = 0.25$$

$$1.40 = (-0.38 \times 0.25) + c$$

$$c = 1.50 \text{ [1]}$$

Absolute uncertainty in y-intercept = difference between y-intercepts

$$\text{Absolute uncertainty in y-intercept} = 1.52 - 1.50 = 0.02$$

y-intercept = 1.52 ± 0.02 (absolute uncertainty quoted to 1 s.f. and final answer consistent with absolute uncertainty). [1]

7F

a i $f = Am^q$

$$\log f = \log A + q \log m \text{ [1]}$$

$$\text{Gradient} = q$$

$$\text{Therefore } q = 0.5 \text{ [1]}$$

$$\text{y-intercept} = \log A$$

$$A = 10^{1.6} = 39.8 = 40 \text{ [1] [allow 2 or 3 s.f.]}$$

ii $f = 40 \times 2.00^{0.5} \text{ [1]} = 57 \text{ Hz [1]}$

(using 3 s.f. value of $f = 56.3 \text{ Hz}$)

b i $A = pe^{-qt}$

$$\ln A = \ln p - qt \text{ [1]}$$

$$\text{gradient} = -q$$

$$q = 0.0305 \text{ [1]}$$

$$\text{y-intercept} = \ln p$$

$$p = e^{\text{y-intercept}}$$

$$p = 25.0 \text{ [1]}$$

ii $A = pe^{-qt}$

$$A = 25.0e^{-0.0305 \times 20} \text{ [1]}$$

$$A = 13.6 \text{ [1]}$$

Chapter 8: A Level practice questions

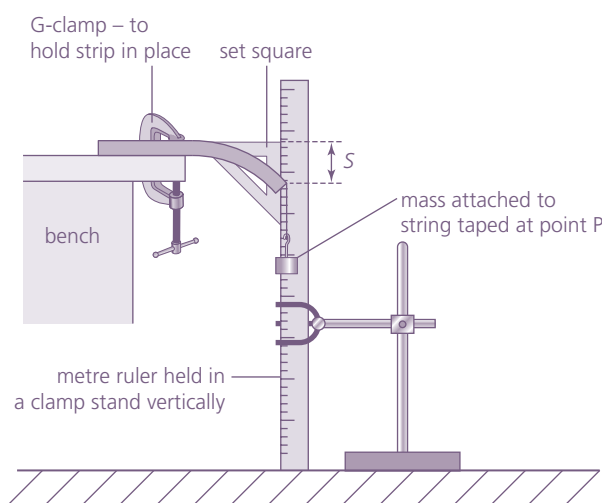
Cambridge Assessment International Education bears no responsibility for the example answers to questions taken from its past question papers. These have been written by the author of the book.

- 1 When marking your answer underline any points listed below that you made in your answer. If most of the points below are underlined, then this is a good answer. If there are gaps, identify these and try to add this level of detail in your answer to the next question.

Apparatus diagram:

Suitable labelled diagram drawn showing how the strip is fixed to the bench, how s is measured accurately and how M is attached.

For example:



(Instead of a G-clamp you could use a heavy mass; the mass could be taped on top of the strip with centre over point P ; to ensure ruler is vertical you could suspend a plumb line.)

Variables: L is the independent variable; s is the dependent variable; and M , t , E and b are control variables.

Method: Measure the thickness, t , and width, b , of the strip using a micrometer/calipers along the length and find mean values. Keep these values constant by using the same strip throughout the experiment.

Clamp the strip to the bench using a G-clamp. Measure the length, L , using a ruler. Measure L on both sides to ensure the strip is perpendicular to the bench.

Use a clamp stand to clamp the metre ruler in place vertically. Use a set square to ensure the ruler is vertical by lining up to the strip when there is no load attached. Record the reading on the vertical ruler.

Measure the mass, M , using a balance and use the same mass throughout the experiment. Attach the mass to the strip at point P using a piece of string taped at point P .

When the strip is stationary, read the reading on the vertical ruler and record. The value of s will be the difference between this reading and the initial reading when the ruler was unloaded.

Remove the load and add again to make a repeat reading of s . Determine the average value of s .

Repeat the method for different values of L .

Safety: The strip may snap so wear goggles to protect your eyes.

The mass may fall so place a cushion under the hanging mass to catch it if it does and prevent you from putting your feet underneath.

Analysis: Plot a graph of s (y -axis) against L^3 (x -axis).

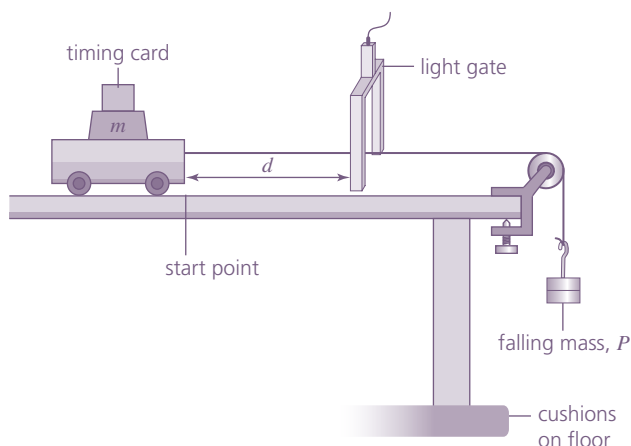
The relationship is valid if the graph is a straight line through the origin. Determine the gradient and use it to find E .

The Young modulus can be calculated using $E = \frac{4Mg}{\text{gradient} \times bt^3}$

- 2 When marking your answer underline any points listed below that you made in your answer. If most of the points below are underlined, then this is a good answer. If there are gaps, identify these and try to add this level of detail in your answer to the next question.

Apparatus diagram:

Suitably labelled diagram showing how the mass, P , is attached to the trolley via the string and the pulley.



[Instead of a light gate you could use a ticker tape timer to determine final speed or you could use a stopwatch to measure the time taken for the trolley to travel distance, d , and determine average speed. The final speed is $2 \times$ average speed. To improve this measurement you would need to increase d or film a stopwatch in view as the trolley moves.]

Variables: Independent variable is the mass, m ; dependent variable is the speed, v ; control variables are the distance, d , and the mass, P .

Method: Check the surface is horizontal using a spirit level.

Mark the start and end points and measure the distance between them using a ruler. This is d . This will remain the constant in each experiment. Place the light gate over the end point.

Use a ruler to measure the width of the timing card passing through the light gate. Attach the timing card to the trolley. It must pass through the light gate and be taller than the mass m .

Use a balance to find the mass of P , and keep this constant throughout the experiment.

Tie a piece of string securely to the trolley and pass over the pulley on a clamp. Tie P to the string as shown in the diagram.

Find the mass m using a balance and record the value. Secure m to the trolley using tape. Release the trolley and record the time, t , from the light gate. Repeat the experiment. Determine an average value of t . Repeat the experiment again with an increased mass, m .

The speed of the trolley, v , is determined using the equation $v = \text{width of time card} / \text{time from light gate}$.

Safety: Place cushions under the mass P to prevent it hitting the floor, or landing on your feet. Place a barrier in front of the pulley to stop the trolley from coming off the end of the bench.

Analysis: Plot a graph with $1/v^2$ versus m [or m against $1/v^2$]

The relationship is correct if you get a straight-line graph with a y -intercept.

Determine the gradient of your graph

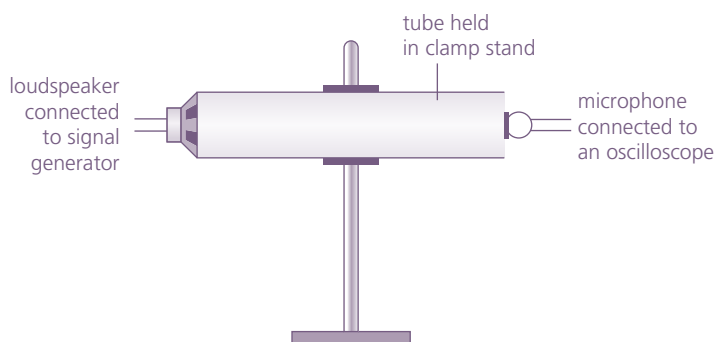
$$Q = Pg - \frac{1}{\text{gradient} \times 2d} \quad \left[\text{or } Q = Pg - \frac{\text{gradient}}{2d} \right]$$

$$R = 2d \times [Pg - Q] \times y\text{-intercept} \text{ or } R = \frac{y\text{-intercept}}{\text{gradient}} \quad [\text{or } -y\text{-intercept}]$$

- 3** When marking your answer underline any points listed below that you made in your answer. If most of the points below are underlined, then this is a good answer. If there are gaps, identify these and try to add this level of detail in your answer to the next question.

Apparatus diagram:

A diagram showing the tube supported with a loudspeaker connected to a signal generator at one end and a microphone in line with the edge of the tube and connected to an oscilloscope at the other. For example:



(If you do not remember symbols for oscilloscope, microphone and loudspeaker, a labelled drawing will be sufficient.)

Variables: Independent variable is d ; dependent variable is f ; control variable is L .

Method: Measure the internal diameter of the tube using calipers. Measure at each end of the tube, in more than one place in different directions along the length of the tube and calculate the mean value.

Measure the length, L , at several places around the circumference of the tube using a ruler. This must be constant in each experiment.

Set up the experiment as shown with the loudspeaker and microphone in line with each other at either end of the tube. Perform the experiment in a quiet room.

Start with a low frequency sound and increase frequency until a maximum amplitude sound is detected. Continue to increase and then decrease frequency to make sure correct frequency is identified.

Once frequency is identified, use the oscilloscope to determine the time period. Identify one complete wave and count the number of divisions. Time period, $T = \text{number of divisions} \times \text{time base [s/div]}$.

Calculate frequency, f , using $f = 1/T$.

Repeat with different diameter tubes.

Safety: Use a low volume of sound to prevent damage to hearing.

Analysis: Plot a graph of $1/f$ versus d (or d versus $1/f$)

If the relationship holds this will be a straight line graph with a y -intercept.

$$v = \frac{2L}{y\text{-intercept}} \quad (\text{or } v = \text{gradient} \times k)$$

$$k = \text{gradient} \times v \quad \left(\text{or } k = -\frac{2L}{y\text{-intercept}} \right)$$

4 a gradient = q and y -intercept = $\log p$ [1]

b

T/K	I/mA	$R/10^3\Omega$	$\log(T/K)$	$\log(R/10^3\Omega)$
303	1.0 ± 0.1	9.40 ± 1.16	2.481	0.973 ± 0.051
313	1.6 ± 0.1	5.88 ± 0.45	2.496	0.769 ± 0.032
323	2.4 ± 0.1	3.92 ± 0.21	2.509	0.593 ± 0.023
333	3.7 ± 0.1	2.54 ± 0.10	2.522	0.405 ± 0.027
343	5.5 ± 0.1	1.71 ± 0.05	2.535	0.233 ± 0.013
353	8.7 ± 0.1	1.08 ± 0.02	2.548	0.033 ± 0.008

Values of R as shown on the table can also be written to 1 decimal place. Calculated using $R = E/I = 9.4/I$ [1]

Values of $\log R$ as shown on the table – if values of R written to 1 decimal place, then values of $\log R$ must be written to 2 d.p. [1]

Uncertainties for R as shown in table (these values are calculated using max – mean method ($R_{\text{max}} - R$)). [1] (Values using ($R_{\text{min}} - R$) or $\frac{1}{2}(R_{\text{max}} - R_{\text{min}})$ will be slightly different.) [1] e.g. for first row ± 0.95 and ± 1.05 , respectively, second row ± 0.41 and ± 0.43 etc. You could also determine the uncertainty by adding percentage or fractional uncertainties and converting to absolute uncertainties.

Uncertainties for $\log R$ consistent with uncertainties for R (these values calculated using max – mean method ($\log R_{\text{max}} - \log R$)). [1]

c i Graph plotted correctly (each within half a small square and point must be smaller than half a square so use dot). [1]

All error bars for $\log R$ plotted correctly. Each bar to within $\frac{1}{2}$ small square and same length either side of point. [1]

ii Line of best fit drawn and labelled. [1]

Line of worst fit drawn – steepest or shallowest line that passes through all the error bars. [1]
(You can only have this mark if all the error bars were drawn.)

iii Gradient of line of best fit calculated using measurements of Δy and Δx taken from data points further than half the line apart/gradient calculated using $= \frac{\Delta y}{\Delta x}$ /same sign as your graph so must be negative (approximately -14.0). [1]

Gradient of line of worst fit found and uncertainty determined using
uncertainty = gradient of line of best fit – gradient of line of worst fit [1]

iv Pair of data points taken from line of best fit substituted in $y = mx + c$. Equation rearranged to find c (approximately 36) [1]

d p determined using y -intercept, $p = 10^{y \text{ intercept}}$ (approximately 1×10^{36}) [1]

q is equal to the gradient of the line of best fit [1] answer given to 2 or 3 s.f.

e Substituting values of p and q into $R = pT^q$

$$15 = 1 \times 10^{36} T^{-14}$$

$$T = \sqrt[14]{\frac{15}{1 \times 10^{36}}}$$

$$T = 307 \text{ [1]}$$

or substitute values for R , p and q into $\log R = \log p + q \log T$ and rearrange

$$\log 15 = 36 - 14 \log T$$

$$\log T = (36 - \log 15)/14$$

$$T = 307$$

Answer T approximately 310 to 2 s.f. Your answer will depend on your values for p and q .

5 a $\ln V = \ln \frac{Q_0}{C} - \frac{t}{RC}$

$$\text{gradient} = \frac{-1}{RC}$$

$$y\text{-intercept} = \ln \frac{Q_0}{C} \quad [1] \quad (\text{Both answers needed for mark})$$

b

t/s	V/V	$\ln (V/V)$
0	6.2 ± 0.2	1.825 ± 0.031
6	4.6 ± 0.2	1.526 ± 0.043
12	3.4 ± 0.2	1.224 ± 0.057
18	2.6 ± 0.2	0.956 ± 0.074
24	2.0 ± 0.2	0.693 ± 0.095
30	1.4 ± 0.2	0.336 ± 0.134

Correct values of $\ln V$ in table recorded to 2 or 3 decimal places. [1]

Absolute uncertainties in $\ln V$ calculated using the max min method ($\ln V_{\max} - \ln V$). [1] Values using $\ln V - \ln V_{\min}$ or $\frac{1}{2}[\ln V_{\max} - \ln V_{\min}]$ may be slightly different.

- c i** Graph plotted correctly (each within half a small square and point must be smaller than half a square so use dot). [1]

All error bars for $\log V$ plotted correctly. Each bar to within $\frac{1}{2}$ small square and same length either side of point. [1]

- ii** Line of best fit drawn and labelled. [1]

Line of worst fit drawn – steepest or shallowest line that passes through all the error bars. You can only have this mark if all the $\ln V$ error bars were drawn. [1]

- iii** Gradient of line of best fit calculated using measurements of Δy and Δx taken from data points further than half the line apart/gradient calculated using $= \frac{\Delta y}{\Delta x}$ /same sign as your graph so must be negative (approximately -0.05). [1]

Gradient of line of worst fit found and uncertainty determined using

uncertainty = gradient of line of best fit – gradient of line of worst fit [1]

- iv** y -intercept read from the axes correctly ($\pm$ half a small square) (approximate value = 1.8) [1]

OR Pair of data points taken from line of best fit substituted in $y = mx + c$. Equation rearranged to find c .

- d i** C determined using gradient

$$\text{Gradient} = \frac{-1}{RC}$$

$$\text{e.g. } -0.05 = \frac{-1}{39000C}$$

$$C = 5.13 \times 10^{-4} \quad [\text{answer given to 2 or 3 s.f.}] \quad [1]$$

$$y\text{-intercept} = \ln \frac{Q_0}{C}$$

$$\text{e.g. } 1.8 = \ln \frac{Q_0}{C}$$

$$e^{1.8} = \frac{Q_0}{C}$$

$$Q_0 = C \times e^{1.8} = 5.13 \times 10^{-4} \times e^{1.8} \\ = 3.10 \times 10^{-3} \text{ [answer given to 2 or 3 s.f.] [1]}$$

Correct units given: $Q_0 = 3.10 \times 10^{-3} \text{ C}$ [1]

and $C = 5.13 \times 10^{-4} \text{ F}$

ii Absolute uncertainty in $C = (\text{fractional uncertainty in } R + \text{fractional uncertainty in the gradient}) \times C$

e.g. if absolute uncertainty in gradient is 0.02,

absolute uncertainty in $C = [0.05 + (0.02/0.05)] \times 5.13 \times 10^{-4}$

absolute uncertainty in $C = 2 \times 10^{-4} \text{ F}$ [1]

e
$$V = \left(\frac{Q_0}{C} \right) e^{\frac{-t}{RC}}$$

$$V = e^{y \text{ intercept}} \times e^{\text{gradient} \times 60}$$

e.g. $V = e^{1.8} \times e^{-0.05 \times 60} = 0.301 \text{ V}$ [1]

or

$$\ln V = \ln \frac{Q_0}{C} - \frac{t}{RC}$$

$$\ln V = y\text{-intercept} - [60 \times \text{gradient}]$$

or substitute values of Q_0 , R and C into the equation

6 a $Au = (M + m + A)v$

Rearrange equation:

$$\frac{Au}{v} = (M + m) + A$$

$$\frac{1}{v} = \frac{(M + m)}{Au} + \frac{1}{u}$$

$$\text{Gradient} = \frac{1}{Au}$$

$$y\text{-intercept} = \frac{1}{u} \text{ [1]}$$

b Values of $[M + m]$ and $1/v$ as shown in the table ($1/v$ to 3 or 4 s.f.) [1]

m/g	$(M + m)/\text{g}$	v/cms^{-1}	$\frac{1}{v}/\text{s cm}^{-1}$
50	380 ± 19	4.42	0.2262
150	480 ± 24	3.92	0.2551
250	580 ± 29	3.40	0.2941
350	680 ± 34	3.02	0.3311
500	830 ± 42	2.58	0.3876
600	930 ± 47	2.33	0.4292

Absolute uncertainties in $(M + m)$, as shown in the table [1] calculated by adding the absolute uncertainties in M and m .

e.g. $(0.05 \times 50) + (0.05 \times 330) = 19 \text{ g}$

- c i** Graph plotted correctly (each within half a small square and point must be smaller than half a square so use dot). [1]
- All error bars for $[M + m]$ plotted correctly. Each bar to within $\frac{1}{2}$ small square and same length either side of point. [1]
- ii** Line of best fit drawn and labelled. [1]
- Line of worst fit drawn – steepest or shallowest line that passes through all the error bars. You can only have this mark if all the $\ln V$ error bars were drawn. [1]
- iii** Gradient of line of best fit calculated using measurements of Δy and Δx taken from data points further than half the line apart/gradient calculated using $= \frac{\Delta y}{\Delta x}$ /same sign as your graph so must be positive (approximately 0.0004). [1]
- Gradient of line of worst fit found and uncertainty determined using
- uncertainty = gradient of line of best fit – gradient of line of worst fit [1]
- iv** Pair of data points taken from line of best fit substituted in $y = mx + c$. Equation rearranged to find c (approximately $c = 0.08$) [1]
- Pair of data points taken from line of **worst** fit substituted in $y = mx + c$. Equation rearranged to find c for worst fit line.
- uncertainty = y -intercept of line of best fit – y -intercept of line of worst fit [1]
- d i** y -intercept = $\frac{1}{u}$
- e.g. $u = 1/0.08 = 12.5$ (answer given to 2 or 3 s.f. max) [1]
- Gradient = $\frac{1}{Au}$
- e.g. $A = \frac{1}{\text{gradient} \times 12.5} = \frac{1}{0.0004 \times 12.5}$
- $A = 200$ (answer given to 2 or 3 s.f. max) [1]
- ii** % uncertainty in A = % uncertainty in y -intercept + % uncertainty in the gradient
- % uncertainty in A =
- $$\left(\frac{\text{absolute uncertainty in } y\text{-intercept}}{y\text{-intercept}} + \frac{\text{absolute uncertainty in gradient}}{\text{gradient}} \right) \times 100 \quad [1]$$
- e** Rearrange the equation to make m the subject and substitute A , u and $v = 2.0 \text{ ms}^{-1}$
- e.g. $Au = (M + m + A)v$
- $$\frac{Au}{v} - (M + A) = m$$
- $$m = \frac{200 \times 12.5}{2} - (330 + 200) = 720 \text{ g} \quad [1]$$