

SAMPLE

This is a real A Level Paper 5 I marked for a student, shown as they got it back, in their own handwriting. The only change is that their name is removed. Every mark and note is what they received.

YOUR OWN PAPER

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Here's your Paper 5.

9702/51, May/June 2024 (Paper 5, Variant 1). Marked against Cambridge's published mark scheme for that paper, the way I marked scripts for Cambridge.

	Q1 PLAN	Q2 ANALYSIS
17 / 30 YOUR MARK	14 / 30 WORST CASE	10/15
		7/15

That's a B on this paper: the B line for 9702/51 in that series was 16 out of 30 and the A line 19, so you're two marks off an A. Worst case: if your examiner was having a bad day, the three marks I gave you on the benefit of the doubt could go the other way, and 17 becomes 14, a C (the C line was 13). So the green cards matter as much as the marks you lost. Your plan was strong. You scored on heating the cylinder to a uniform temperature, the stopwatch, measuring L and d , keeping T_R constant, the choice of graph, and on the extra detail: burns, the balance, the surface area and the mean diameter. Most of what you lost was in the numbers of Question 2: significant figures, plotting, uncertainties and units. The two marks for U and Z went because they don't match the axes you said you'd use (note 4).

The one thing I'd fix before your next Paper 5

Treat Question 2 as a checking job, line by line, and run the same four checks every time. They cost you 8 marks here:

- **Significant figures, and everything in the table.** f has four, so $1/f$ needs four. Rounding it to 1.12, 1.11 and so on moved your points by up to eight small squares. The uncertainties go in the table too, with a $\pm$. (note 5)
- **Plot from your own table, point by point,** against the nearest heavy grid line, and draw each error bar with a short line across each end, measured end to end. (notes 6, 7 and 8)
- **An uncertainty is a difference.** Best-fit value minus worst-line value, written with both numbers. (notes 9 and 10)
- **Unit and sign on every final answer.** f_s is in Hz, and k is a speed, so it can't be negative. (note 11)

In Question 1: vary t , name one thermometer and show it on the cylinder, average your sensors, and make U and Z match the axes you choose. (notes 1 to 4)

Question 1: which mark is which

The scheme prints nine marks for the plan (MP1 to MP9, in the order below) and then up to six more for extra detail (D1 to D10). Your ticks on that question, and the notes below, use these labels.

MARK	WHAT IT'S FOR	YOU	MARK	WHAT IT'S FOR	YOU
MP1	t independent, T_C dependent	no	MP6	measure L and d	yes
MP2	T_R kept constant	yes	MP7	graph of $\ln(T_C - T_R)$ against t	yes
MP3	labelled diagram of the cooling cylinder	no	MP8	U from the gradient	no
MP4	method to heat the cylinder uniformly	yes	MP9	Z from the y-intercept	no
MP5	method to determine t	yes			

Extra detail, capped at 6, and you scored 5: **D1** burns precaution, **D3** measuring the mass, **D4** waiting for a uniform temperature, **D5** the area formula (BOD), **D6** the mean diameter. Not given: D9 several sensors averaged (note 3), D2 constant insulation thickness, D7 and D8 finding c by heating the cylinder electrically, D10 "the relationship is valid if the graph is a straight line".

Where the other marks went

The blue numbers match the blue circles on your script.

1 Q1, defining the problem (MP1) 1 MARK

The relationship is about how T_C changes as t changes, so t is what you vary and T_C is what you measure. In step 13 you say t is the independent variable, which is right, but the initial plan you wrote on the question page calls time the dependent variable, and your steps 6 and 7 read T_C after one fixed time (10 minutes) for different starting temperatures, so t never changes. Two answers that disagree can't both be credited. Start the stopwatch and read T_C at several values of t as the cylinder cools (for example every minute).

2 Q1, the diagram (MP3) 1 MARK

The cylinder packed in insulation was the right idea. Two things stopped the mark. Your label offers two instruments, "thermistor / multiple temperature sensors", and an examiner won't pick one for you. And the thermistor, as drawn, can't give a temperature: its resistance changes with temperature, so it needs a current through it and a calibration, and here it's wired straight to a voltmeter with nothing to drive a current. Name one instrument and put it where it measures the surface temperature:

Thermometer touching the surface of the cylinder, underneath the insulation. Insulation covering the whole cylinder, ends included. Label both.

EXAMINER REPORT, JUNE 2024

"The temperature sensor needs to be positioned between the insulation and the cylinder for it to measure the surface temperature of the cylinder."

3 Q1, extra detail (5 of 6) 1 MARK

The extra-detail marks stop at 6 and you reached 5: burns, the mass, a uniform starting temperature, the area and the mean diameter. "Several sensors" was close: you use "different temperature sensors" in step 6, but your mean in step 8 is over repeats. The mark is for averaging the sensors at the same moment:

Fix three temperature sensors at different points on the surface of the cylinder, under the insulation. At each time t, T_C = mean of the three readings.

Other routes to the sixth mark: keep the insulation the same thickness every time; find c by heating the cylinder itself with an electrical heater, $c = E/(m \times \text{temperature rise})$, with E from a joulemeter or IVt; and say "the relationship is valid if the graph is a straight line". (Your step 10 heats the water bath, so most of the energy IVt goes into the water, not the cylinder. That wouldn't give c for the metal.)

4 Q1, finding U and Z (MP8, MP9) 2 MARKS

Your graph scored (MP7) because you chose the right two things to plot, $\ln(T_C - T_R)$ and t. In step 13

you've flipped the axes, $\ln(T_C - T_R)$ on the x-axis and t on the y-axis, and that's allowed. But matching your equation to $y = mx + c$ is what tells you, and the examiner, which quantity is on which axis, and everything after it has to be consistent with that. You matched $\ln(T_C - T_R) = -UAt/mc + \ln Z$ to $y = mx + c$, which puts $\ln(T_C - T_R)$ on the y-axis, and then said it goes on the x-axis. If you plot it the way you said, the equation that matches $y = mx + c$ isn't the one you wrote:

$$t = -(mc/UA) \ln(T_C - T_R) + (mc/UA) \ln Z$$

so gradient = $-mc/UA$ and y-intercept = $(mc/UA) \ln Z$

Your U and Z in step 14 fit the other way round, so they don't score for the graph you described. Choose your axes, match to $y = mx + c$, and keep everything after it consistent. Either of these would have scored both marks:

$\ln(T_C - T_R)$ on y, t on x:

gradient = $-UA/mc$, so $U = -(\text{gradient} \times mc)/A$

y-intercept = $\ln Z$, so $Z = e^{\text{y-intercept}}$

t on y, $\ln(T_C - T_R)$ on x:

gradient = $-mc/UA$, so $U = -mc/(A \times \text{gradient})$

y-intercept = $(mc/UA) \ln Z = -\text{gradient} \times \ln Z$, so $Z = e^{-(\text{y-intercept})/\text{gradient}}$

EXAMINER REPORT, JUNE 2024

"Credit was not awarded to candidates who did not correctly identify appropriate axes for a graph to plot."

5 2(b) 2 MARKS

Your v values are all right. Two things cost the marks. First, the $1/f$ column: f is given to 4 significant figures, so $1/f$ needs 4 (or 5): **1.118, 1.110, 1.101, 1.092, 1.083, 1.074**. You wrote 1.12, 1.11, 1.10, 1.09, 1.08, 1.07, which puts your first point about 3 small squares too high on the graph and your last about 8 too low. Second, the uncertainties: your six values and your working are right, but they're beside the table with no $\pm$. The question says to include them in v , so they go in the column:

$$v = 3.5 \pm 0.4, \text{ because } (3.9 - 3.1)/2 = 0.4$$

EXAMINER REPORT, JUNE 2024

"Since f was recorded to four significant figures, values of $1/f$ should have been recorded to four (or five) significant figures."

6 2(c)(i), the six points 1 MARK

Your heights match your table. The horizontal positions don't: every point is to the left of the v you tabulated. Each point must be within half a small square (0.1 of a unit on this axis). These are my readings from your scan, to within 0.1, so check them on your paper:

v IN YOUR TABLE 3.5 6.3 8.7 11.4 13.9 16.2

WHERE YOU PLOTTED IT 3.3 5.7 7.9 11.2 13.5 15.9

Read the x -value against the nearest **heavy** grid line (7.0 and 9.0 for the third point, for example), and tick each row of the table off as you plot it.

7 2(c)(i), the error bars 1 MARK

The total length of each bar is twice the uncertainty, so the six should be 0.8, 0.8, 1.0, 1.0, 1.2 and 1.2 long. Yours measure about 0.8, 0.8, 1.0, 1.0, 1.1 and 1.1: the last two are short by half a small square or a bit more, and the last one sits lopsided about its cross. Each bar must be symmetrical. Mark the cross first, measure out the same distance each side against the grid, and draw a short line across each end, $| \text{---} + \text{---} |$, not an arrowhead, $\leftarrow + \rightarrow$: the end line shows exactly where the bar stops.

EXAMINER REPORT, JUNE 2024

"Candidates need to take greater care over the accuracy of the error bars and ensure that the error bars are symmetrical."

EXAMINER REPORT, NOVEMBER 2025 (9702/51)

"A clear small line should be drawn at the end of each bar."

8 2(c)(ii), the line of best fit 1 MARK

Your line is a fair fit to the points you plotted, but because those points are off it comes out steeper than a line through correctly plotted points: it crosses $y = 1.080$ at about $v = 13.5$, and the correct line crosses it near 14.5, about five small squares further right. Fix the plotting and this mark comes with it.

9 2(c)(iii), the uncertainty in the gradient 1 MARK

The gradient of the worst line is right and the substitution is clear. The uncertainty is where it went wrong: you wrote $(-3.9 \times 10^{-6}) - (-3.894 \times 10^{-6})$, which is the best-fit gradient twice, once rounded and once not, and gave 3×10^{-9} . The uncertainty is the difference between the best-fit gradient and the worst-line gradient: $(-3.894 \times 10^{-6}) - (-3.676 \times 10^{-6}) = -2.2 \times 10^{-7}$, so the uncertainty is 2.2×10^{-7} .

EXAMINER REPORT, JUNE 2024

"how the uncertainty is determined from the gradients of the line of best fit and the worst acceptable line."

10 2(c)(iv), the uncertainty in the y-intercept 1 MARK

The intercept of the worst line is right. Then you divided the difference by 2. With one worst line, the uncertainty is the whole difference: $1.1330 \times 10^{-3} - 1.1309 \times 10^{-3} = 2.1 \times 10^{-6} \text{ Hz}^{-1}$. (Half the difference only appears when you draw both a steepest and a shallowest worst line and halve the gap between them.)

EXAMINER REPORT, JUNE 2024

"there must be evidence of subtraction between the y-intercept of the line of best fit and the y-intercept of the worst acceptable line."

11 2(d)(i), f_s and k 1 MARK

You used your y-intercept correctly to get f_s , which scored the first mark. The second needs both final answers right, and two things stopped it. First, **f_s is a frequency, so its unit is Hz**; Hz^{-1} is the unit of $1/f_s$, your y-intercept. Second, the gradient is negative (-3.9×10^{-6}), so $k = -1/(\text{gradient} \times f_s) = -1/(-3.9 \times 10^{-6} \times 909) = +282 \text{ m s}^{-1}$. You put $+3.9 \times 10^{-6}$ against $-1/(f_s k)$ and got -282. A negative speed of sound is your warning sign. One more habit: you rounded the intercept to 1.1×10^{-3} before using it, which changes f_s by about 3% (909 against 883 from 1.133×10^{-3}). Keep the unrounded value until the last line.

EXAMINER REPORT, JUNE 2024

"Candidates were also expected to give the final values of f_s and k to an appropriate number of significant figures and a unit which should have the correct power of ten."

Marks you got, but I'd tighten the wording

These all scored. Three were marked generously (BOD), and the other one needs tidier working. Don't give an examiner any excuse to take a mark away. They mark hundreds of scripts and won't puzzle over yours, so make every step visible. You don't need full sentences: step-by-step working, with a few words to signpost each step, is clearer and quicker.

A Q1, the surface area (D5) **BOD**

Your worked line in step 3 is right, but two things put it at risk. Your pi looks like an x, so " $2x(d/2)L$ " reads as a different formula: give pi its flat top. And the initial plan you wrote on the question page gives $A = 2\pi(d/2)^2 \times L$, which is wrong, and you didn't cross it out, so the examiner has two formulas to choose between. Cross out anything you've replaced, and give one formula:

$$A = \pi d L + 2 \times \pi (d/2)^2 = \pi d L + \pi d^2/2$$

B Q1, the mean diameter (D6)

You made the point, so this scored. But "measure at different lengths and find mean" is squeezed in beside step 1, which is about the mass, and an examiner reading step 2 for the diameter could miss it. Put each point in the step it belongs to:

Measure d at three or more positions along the length of the cylinder, and take the mean value of d.

C 2(c)(ii), the worst acceptable line **BOD**

Your worst line does reach every bar, but it only touches the tips of bars 3 and 6. Draw it so it clearly **crosses** each bar, and label both lines.

The line is the shallowest one that still crosses all six bars. Check by sliding a ruler: if it can't be shallower without missing a bar, it's the worst acceptable line.

D 2(e), the speed **BOD**

Your method is right and you carried your own k and f_s through, which is what scored. But the question asks for a **speed**, and you gave -22. A negative answer to a speed question is your cue to go back and check: here it comes from the sign of k. f is above f_s , so the car is approaching and v is positive. Your first line also has $280 - v$ in the denominator where your k gives $-280 - v$. With $k = +282 \text{ m s}^{-1}$, one step per line:

$$\begin{aligned} f &= f_s k / (k - v) \\ 987.8 &= 910 \times 282 / (282 - v) \\ 282 - v &= 910 \times 282 / 987.8 = 259.8 \\ v &= 282 - 259.8 = 22 \text{ m s}^{-1} \end{aligned}$$

Reading the marks on your script

✓ Mark awarded, placed where you earned it

✗ Not awarded

1/2 Your mark for that part

BOD Marked generously. See the green cards for the safer wording

MP3

In Question 1, the mark scheme point that tick is for (MP1 to MP9 in the order the scheme prints them, and the scheme's own D1 to D10 for the extra detail). On your graph the marks are named: Plots, Error bars, Best-fit line, Worst line

Good luck with the real one.

Rich

2

1 Fig. 1.1 shows a small solid metal cylinder of mass m , length L and diameter d .

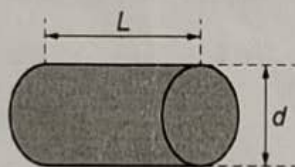


Fig. 1.1

The cylinder is heated to a uniform temperature. The cylinder is then removed from the heat source and the cylinder is wrapped in an insulating material.

The temperature of the room is T_R . At time t after the cylinder starts to cool, the surface temperature of the cylinder is T_C .

It is suggested that T_C is related to t by the relationship

$$(T_C - T_R) = Ze^{-\frac{UAt}{mc}}$$

where A is the total surface area of the cylinder, c is the specific heat capacity of the metal, and U and Z are constants.

Plan a laboratory experiment to test the relationship between T_C and t .

Draw a diagram showing the arrangement of your equipment.

Explain how the results could be used to determine values for U and Z .

In your plan you should include:

- the procedure to be followed
- the measurements to be taken
- the control of variables
- the analysis of the data
- any safety precautions to be taken.

T_C → surface temperature of cylinder

t → time

① To measure: m (mass)
 c (specific heat capacity, data)
 A (total surface area; $2\pi(\frac{d}{2})^2 \times L$)

② time → stopwatch (s) → dependent variable

T_C → thermocouple → heated temperature; range: 50–110°C

③ Analysis: graph of $\ln(T_C - T_R)$ vs t

y-axis
 $m \rightarrow -\frac{UA}{mc}$
 known

$$\ln(T_C - T_R) = \ln Z - \frac{UAt}{mc}$$

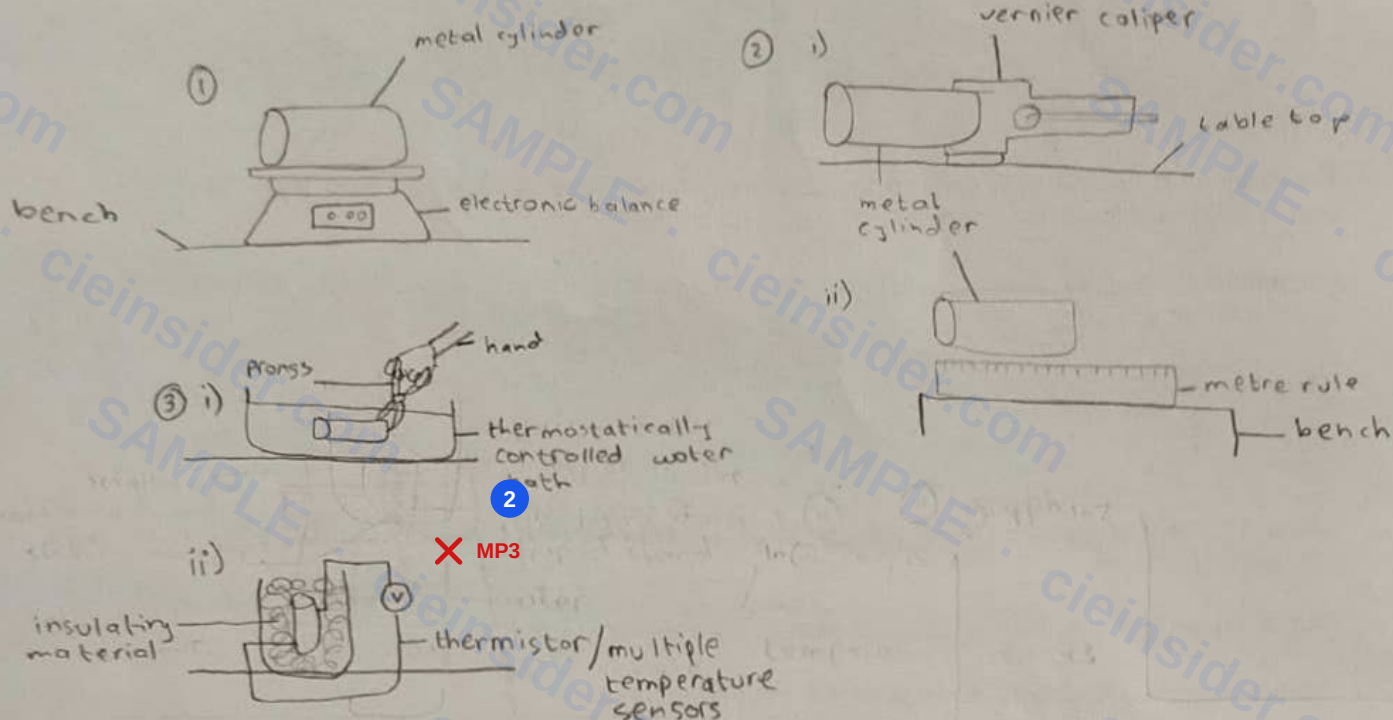
$$\ln(T_C - T_R) = -\frac{UA}{mc}t + \ln Z$$

$$y = mx + c$$

gradient $m = -\frac{UA}{mc}$ → total surface area
 mass ← m → specific heat capacity

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

Diagram



1. Use an electronic balance like in ① to measure the mass m of the cylinder. Note it down. Measure at different lengths and find mean. ✓ D3
2. Use a vernier caliper to find the diameter d of the metal cylinder (②) and find the radius r by $\frac{d_{\text{mean}}}{2}$. ✓ MP6 (d) ✓ D6
3. Use the metre rule to measure L and calculate the surface area using $= 2\pi\left(\frac{d}{2}\right)L + 2\pi\left(\frac{d}{2}\right)^2 = \pi dL + \pi \frac{d^2}{2}$. ✓ MP6 (L) ✓ D5.BOD
4. Immerse the metal cylinder in hot water of constant temperature for at least 15 minutes till the metal is the same temperature throughout. ✓ D4 ✓ MP4
5. Use tongs to lift the cylinder and dry it with a towel. Quickly add it to a glass beaker with insulating material.
6. Start the stopwatch and check T_c using different temperature sensors after a fixed amount of time (e.g. 10 minutes). ✓ MP5

4

7. Temperatures of range $40-90^{\circ}\text{C}$ can be used and the above can be repeated ^{for} at least 5 different values of temperature.
8. Repeat the procedure at least thrice for each set of values to calculate the mean T_c for each temperature. ✗ D3
9. The room temperature, T_a , must be constant throughout the experiment and it should be the same for each set of values. ✓ MP2
10. The specific heat capacity of the material, c , can be calculated experimentally using the equation below:
 $(m = \text{mass of cylinder}) c = \frac{E}{m\Delta T}$; the energy input (E) can be found using $E = IVt$, where I is the current supplied to the water bath, V is the voltage supply and t is the time taken to raise the temperature by ΔT in the water bath.
11. The increase in temperature can be determined by subtracting the initial temperature of the cylinder (which should be equal to T_a) from the temperature of the water bath.
12. Thus, values for c , T_c , T_a , A , t , and m , have been obtained.
13. Comparing $\ln(T_c - T_a) = -\frac{UA}{mc}t + \ln Z$ to $y = mx + c$, draw a graph of $\ln(T_c - T_a)$ on the x -axis (as it is the dependent variable) against t on the y -axis (as it is the independent variable) to get a straight line graph. ✓ MP7
14. $\ln Z$ would be the y -intercept and the gradient would be $-\frac{UA}{mc}$; $U = \frac{-\text{gradient} \times mc}{A}$; $Z = e^{\text{y-intercept}}$. ✗ MP8 ✗ MP9
15. The gradient can be found using $\frac{y_2 - y_1}{x_2 - x_1}$.
16. Caution should be exercised when dealing with high temperatures in the water bath and gloves should be used to prevent burning. ✓ D1

[15]

10/15

5

- 2 A student investigates the sound from a horn attached to a car, as shown in Fig. 2.1.

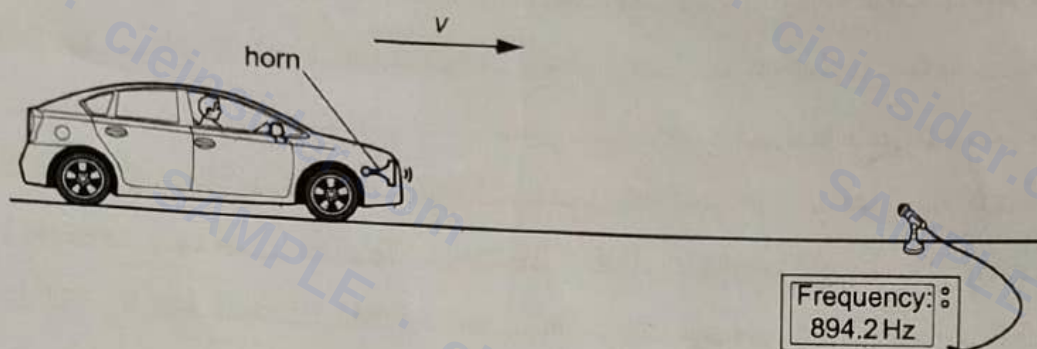


Fig. 2.1 (not to scale)

A microphone is placed at the side of the road and connected to a frequency meter. The car travels towards the microphone. The frequency f of the sound detected by the microphone is read from the frequency meter.

The speed of the car is measured by two speed detectors. The two measurements of speed are v_1 and v_2 . The average speed v of the car is determined from v_1 and v_2 .

The experiment is repeated for different speeds of the car.

It is suggested that f and v are related by the equation

$$f = \frac{f_s k}{k - v}$$

where f_s is the frequency of the sound emitted by the horn and k is a constant.

- (a) A graph is plotted of $\frac{1}{f}$ on the y-axis against v on the x-axis.

Determine expressions for the gradient and y-intercept.

$$f = \frac{f_s k}{k - v}$$

$$\text{y-intercept} = \frac{1}{f_s}$$

$$k - v = \frac{f_s k}{f}$$

$$\text{gradient} = -\frac{1}{f_s k}$$

$$\frac{k - v}{f_s k} = \frac{1}{f}$$

$$\frac{1}{f} = \frac{k}{f_s k} - \frac{v}{f_s k}$$

$$\text{gradient} = \dots\dots\dots -\frac{1}{f_s k}$$

$$\frac{1}{f} = -\frac{v}{f_s k} + \frac{k}{f_s k}$$

$$\text{y-intercept} = \dots\dots\dots \frac{1}{f_s}$$

$$\frac{1}{f} = -\frac{v}{f_s k} + \frac{1}{f_s}$$

comparing to $y = mx + c$

[1]

1/1

6

(b) Values of v_1 , v_2 and f are given in Table 2.1.

Table 2.1

v_1/ms^{-1}	v_2/ms^{-1}	v/ms^{-1}	f/Hz	$\frac{1}{f}/10^{-3}\text{Hz}^{-1}$
3.1	3.9	3.5	894.2	1.12
6.7	5.9	6.3	901.2	1.11
9.2	8.2	8.7	908.0	1.10
11.9	10.9	11.4	915.8	1.09
13.3	14.5	13.9	923.6	1.08
15.6	16.8	16.2	931.2	1.07

$$\frac{3.9 - 3.1}{2} = 0.4$$

$$= 0.4$$

$$= 0.5$$

$$= 0.5$$

$$= 0.6$$

$$= 0.6$$

Calculate and record values of v/ms^{-1} and $\frac{1}{f}/10^{-3}\text{Hz}^{-1}$ in Table 2.1.Include the absolute uncertainties in v .

[2]

0/2

(c) (i) Plot a graph of $\frac{1}{f}/10^{-3}\text{Hz}^{-1}$ against v/ms^{-1} . Include error bars for v .

[2]

0/2

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Label both lines.

[2]

1/2

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

gradient of best fit line:

$(x_1, y_1) = (4.0, 1.117)$ $(x_2, y_2) = (14.4, 1.0765)$

$$\begin{aligned} \text{gradient} &= \frac{y_2 - y_1}{x_2 - x_1} \\ &= \frac{1.0765 - 1.117}{14.4 - 4.0} \\ &= \frac{-4.05 \times 10^{-5}}{10.4} \\ &= -3.894 \times 10^{-6} \end{aligned}$$

gradient of worst acceptable line:

$(x_1, y_1) = (5.0, 1.1125)$ $(x_2, y_2) = (15.2, 1.075)$

$$\begin{aligned} \text{gradient} &= \frac{y_2 - y_1}{x_2 - x_1} \\ &= \frac{1.075 - 1.1125}{15.2 - 5.0} \\ &= \frac{-0.0375}{10.2} \\ &= -3.676 \times 10^{-6} \end{aligned}$$

uncertainty:

$$\frac{(3.9 \times 10^{-6}) - (-3.894 \times 10^{-6})}{2}$$

$$= 3 \times 10^{-9}$$

$$\text{gradient} = -3.9 \times 10^{-6} \pm 3.0 \times 10^{-9} \text{ m}^{-1} \text{ s}^2$$

1/2

$$\frac{\text{Hz}^{-1}}{\text{ms}^{-1}} = \frac{1}{\text{s}} \times \frac{\text{s}}{\text{m}} = \text{m}^{-1}$$

7

Plots X

6

(4.0, 1.117)

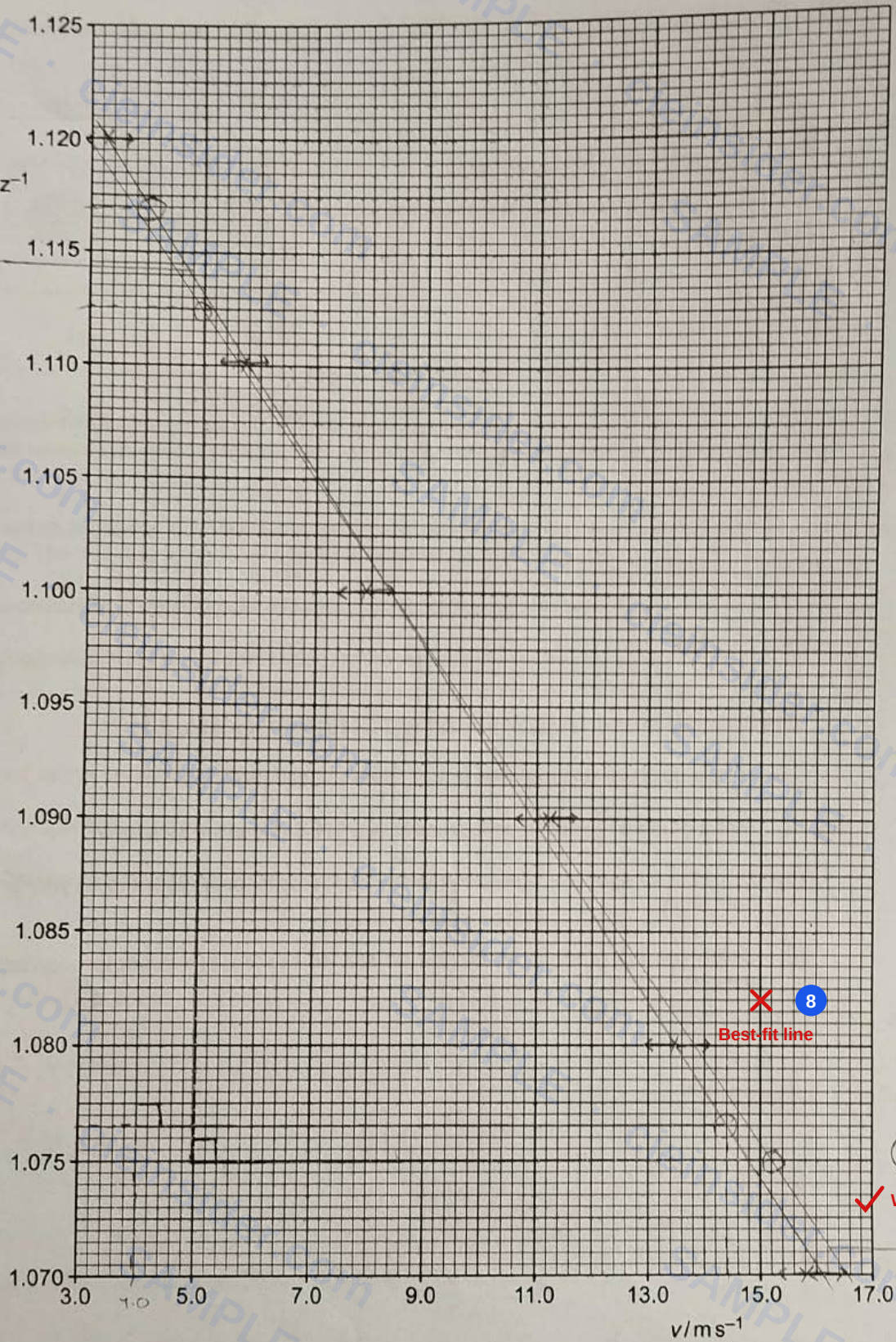
$\frac{1}{f} / 10^{-3} \text{Hz}^{-1}$

best fit line

(9.0, 1.1125)

Error bars X

7



[Turn over

8

- (iv) Determine the y-intercept of the line of best fit. Include the absolute uncertainty in your answer.

uncertainty

$$\frac{(1.133 \times 10^{-3}) - (1.13088 \times 10^{-3})}{2}$$

$$= 1.06 \times 10^{-6}$$

10

$$y = mx + c, \text{ taking } (4.0, 1.117)$$

$$1.117 \times 10^{-3} = (-3.894 \times 10^{-6} \times 4) + c$$

$$c = 1.133 \times 10^{-3} \text{ Hz}^{-1}$$

(y-intercept of best fit line)

$$y\text{-intercept} = 1.1 \times 10^{-3} \pm 1.1 \times 10^{-6} \text{ Hz}^{-1} \quad [2]$$

1/2

- (d) (i) Using your answers to (a), (c)(iii) and (c)(iv), determine the values of f_s and k . Include appropriate units.

$$k = -282.05$$

$$\frac{1}{f} = \frac{-v}{f_s k} + \frac{1}{f_s}$$

$$1.1 \times 10^{-3} = \frac{1}{f_s}$$

$$f_s = 909.09$$

$$y = \frac{1}{f_s}$$

intercept

$$\text{gradient} = \frac{-1}{909.09 \times k}$$

$$\text{gradient} = \frac{-1}{f_s k}$$

$$3.9 \times 10^{-6} = \frac{-1}{909.09 k}$$

$$f_s = 910 \text{ Hz}$$

$$k = -280 \text{ ms}^{-1}$$

[2]

11

1/2

- (ii) Determine the percentage uncertainty in k . $m = \frac{-1}{f_s k}$

$$\Delta D = \text{sum of uncertainties of } f_s \text{ and gradient}$$

$$= \left(\frac{3.0 \times 10^{-6}}{3.9 \times 10^{-6}} \right) \times 100 + \left(\frac{1.1 \times 10^{-6}}{1.1 \times 10^{-3}} \right) \times 100$$

$$= 0.07692\% + 0.1\%$$

$$= 0.1769\%$$

$$\text{percentage uncertainty in } k = 0.18\% \quad [1]$$

1/1

- (e) The experiment is repeated. Determine the speed v that gives a value of f of 987.8 Hz.

$$f = \frac{f_s k}{k - v}$$

$$v = -22.05$$

$$987.8 = \frac{910 \times -280}{280 - v}$$

$$987.8(280 - v) = 910 \times -280$$

$$-280 - v = -257.947$$

$$v = -22.05 \text{ ms}^{-1} \quad [1]$$

[Total: 15]

1/1

$$f = \frac{f_s k}{k - v}$$

$$f(k - v) = f_s k$$

$$k - v = \frac{f_s k}{f}$$

$$k = \frac{f_s k}{f} + v$$

$$= 112$$

$$f(k - v) = f_s k$$

$$k - v = \frac{f_s k}{f}$$

$$-v = \frac{f_s k}{f} - k$$

$$= \frac{910 \times -280}{987.8} - (-280)$$

$$-v = 22.05$$

$$v = -22.05$$

$$m = \frac{-1}{k}$$

$$112 \text{ m}^{-1} \text{ s} = \frac{-1}{112 \text{ k}}$$

$$m^{-1} \text{ s} = \frac{-1}{k}$$

$$\frac{1}{m^{-1} \text{ s}} = k$$

$$\frac{1 \times 10^3}{m \text{ s}^{-1}}$$

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