

WORK LIKE A PHYSICIST

PART 2 OF 3

LESSONS 3–5: THE DROP TEST · HIGHER RAMP, FURTHER TRAVEL? · THE POINT THAT DOES NOT FIT

3

LESSONS

2

PRACTICALS

6

KEY WORDS

“The first principle is that you must not fool yourself, and you are the easiest person to fool.”

RICHARD FEYNMAN, PHYSICIST

ANSWER EDITION FOR TEACHERS AND SELF-MARKING



NAME

CLASS

TEACHER

LAB PARTNER

HOW THIS BOOKLET WORKS

Anyone can have an opinion about how the world works. A physicist has to do something harder: produce **evidence** that convinces people who were not there. This unit teaches you how. Keep the booklet: it is your classwork book *and* your revision guide.



DO NOW

Quick questions from earlier lessons. Remembering again is what makes it stick.



LEARN IT

The explanation, diagrams and worked examples. Read this again when you revise.



TRY IT

Practice that builds up: first with support, then on your own.



PRACTICAL

Plan, record your measurements and work out results from them.



EXAM CORNER

AQA-style questions with a tip on how the marks are given.



REVISE IT

Summary, cover-and-answer questions and an “I can” check to colour in.



Two kinds of question to know. When a sentence has a gap, the choices are printed straight after it, like this: The thing you change is the independent (independent / dependent / control) variable. When you see a box of choices, **draw a ring around** the correct one, as AQA exam papers ask. The thing you measure is the

independent dependent control variable.

THE ROUTE THROUGH THIS PART

#	LESSON	PRACTICAL
03	The drop test Shock absorber practical: three trials and a mean, results tables, bar charts	Drop test: which material absorbs the shock?
04	Higher ramp, further travel? Ramp practical: continuous data, choosing a scale, plotting a line graph	Ramp: distance travelled
05	The point that does not fit Best-fit lines, anomalous results, writing a conclusion with numbers	None: you analyse your Lesson 4 graph

This booklet is Part 2 of 3: Lessons 3–5. The **Physicist’s toolkit** on the last page has every rule, calculation and checklist you need.

THE DROP TEST

AQA Working scientifically WS 2.4, 3.1, 3.3 · Physics and Combined Science

BIG QUESTION Which material makes the best shock absorber, and how would you prove it to someone who was not there?

BY THE END YOU CAN

- recognise a categoric independent variable and what follows from it
- collect three trials for each material and calculate a mean
- build a results table with correct headings and units
- draw a bar chart that would satisfy a strict marker
- name a random and a systematic error in your own practical

trial

mean

results table

bar chart

shock absorber

THE CASE

Why your helmet is made of foam. A cycle helmet is mostly foam that is meant to be crushed. In a crash the foam squashes, so the head stops over a longer time and the force on the skull is smaller. Before a helmet is sold, it is fitted to a head-shaped weight with sensors inside and dropped onto a steel anvil, helmet after helmet. One lucky drop proves nothing.

Same ball. Same height. Only the material changes.



REMEMBER

DO NOW

From earlier lessons. No notes!

1

A categoric independent variable needs a bar chart (a bar chart / a line graph).

a bar chart

2

The variable you change is the independent (independent / dependent / control) variable.

independent

3

A balance reads 0.3 g with nothing on it. This is a systematic (random / systematic) error.

systematic (a zero error)



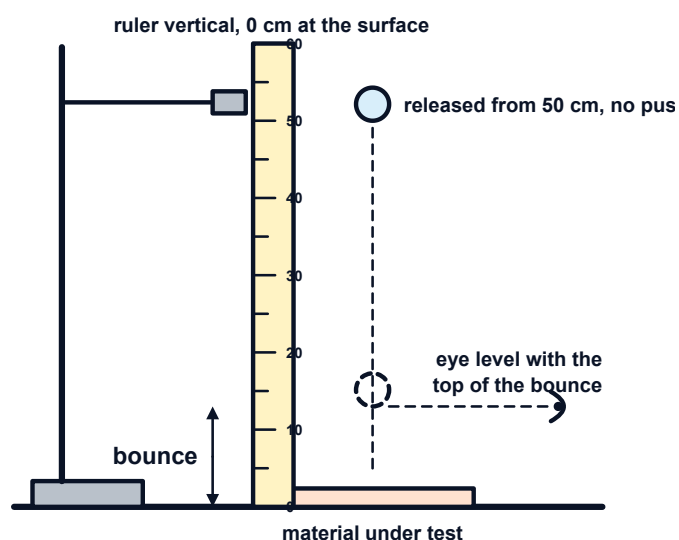
EXPLAIN

BOUNCING BALLS INTO EVIDENCE

Drop a ball onto different materials and measure how high it bounces. The question: **How does the type of material affect the bounce height of a ball?**

VARIABLE	IN THE DROP TEST
Independent	material (categoric)
Dependent	bounce height / cm
Control	same ball; dropped from 50 cm; released, never pushed; ruler in the same place

State control variables with their values: “dropped from 50 cm each time”, not just “same height”.



! Decide before you start. A good shock absorber soaks up the ball's energy instead of giving it back. A ball that barely bounces has left most of its energy in the material. So the best shock absorber gives the **highest lowest** bounce.

WHY EACH STEP OF THE METHOD MATTERS

STEP	REASON
Ruler vertical, 0 cm at the surface	A leaning ruler reads every height too long. A ruler with its zero in the wrong place makes every height wrong by the same amount: a zero error.
Read at eye level	Looking down at the ball lines it up with the wrong mark on the ruler behind it.
First bounce only	Each bounce is lower than the last, so compare the same one every time.
Three trials for each material	One drop could be a fluke. Three show how much the readings vary and give a mean.

■ RESULTS TABLE AND THE MEAN

Material	Trial 1 / cm	Trial 2 / cm	Trial 3 / cm	Mean / cm
sponge	12	15	12	13
cardboard	31	32	27	30
cloth	22	25	22	23
rubber mat	39	35	40	38
bubble wrap	18	14	19	17

- The independent variable goes in the first column.
- Units go in the headings, after a slash, not next to every number.
- One column for each trial, then the mean.
- Write each reading down the moment you take it.

WORKED EXAMPLE Cloth: 22 cm, 25 cm, 22 cm. Calculate the mean.		YOUR TURN Bubble wrap: 18 cm, 14 cm, 19 cm. Calculate the mean.	
ADD	$22 + 25 + 22 = 69 \text{ cm}$	ADD	$18 + 14 + 19 = 51 \text{ cm}$
DIVIDE	$69 \div 3 = 23 \text{ cm}$	DIVIDE	$51 \div 3 = 17 \text{ cm}$
	23 lies between 22 and 25		17 lies between 14 and 19
CHECK	✓	CHECK	✓

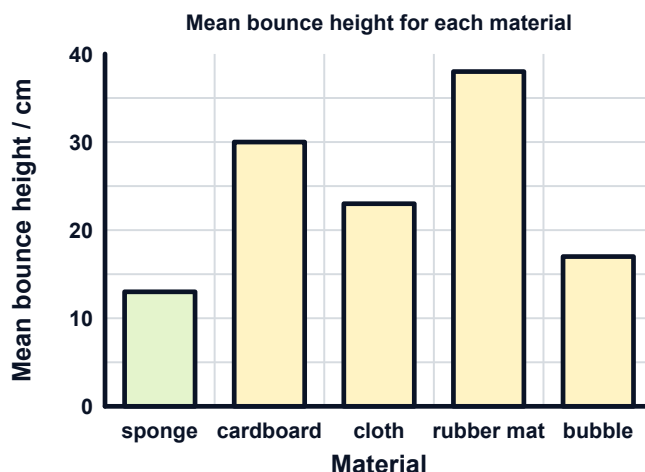


Why a mean? Each trial is a little off, some high and some low. Those differences partly cancel, so the mean is a better estimate than any single trial. A mean must lie between the smallest and largest trial; if yours does not, the arithmetic is wrong. Look across each row first: if one trial is far from the others, repeat it.

■ A BAR CHART THAT SATISFIES A MARKER

- Title: what against what.
- Material on the x-axis; mean bounce height / cm on the y-axis.
- The y-axis starts at 0: the height of a bar is its value.
- Bars of equal width, with equal gaps: the materials are separate things.
- Each bar's height is the **mean**, not trial 1.

Sponge has the lowest mean bounce, 13 cm, so it is the best shock absorber of the five.



■ NAME THE ERROR, MATCH THE FIX

ERROR	IN THE DROP TEST	FIX
Random	judging the top of a fast bounce by eye, so readings vary	film it against the ruler with a fixed camera and pause at the top; take more repeats
Systematic	ruler zero not at the surface, so every height is wrong by the same amount	check that 0 cm is at the surface before you start; repeats do not help



“There was human error” earns nothing. Name the mechanism: “the top of the bounce was judged by eye”. A zero error makes every bar too short by the same amount, so the *order* of the materials stays the same. Random error could swap two materials whose means are close.



- 1 Choose 4 or 5 materials and write them in the table.
- 2 Clamp the ruler vertical, with 0 cm at the surface of the material.
- 3 Hold the ball at 50 cm and release it. Do not throw it or push it down.
- 4 Read the top of the first bounce, with your eye level with it.
- 5 Do three trials for each material, then work out each mean.

STAY SAFE

- Drop the ball vertically; never throw it.
- Make sure the tray and the materials are stable before you release.
- Keep the drop zone clear and do not crowd round it.

RESULTS

- 8 Record every reading as you take it, never from memory at the end.

Material	Trial 1 / cm	Trial 2 / cm	Trial 3 / cm	Mean / cm
sponge	12	15	12	13
cardboard	31	32	27	30
cloth	22	25	22	23
rubber mat	39	35	40	38
bubble wrap	18	14	19	17

- 9 Show one mean calculation in full.

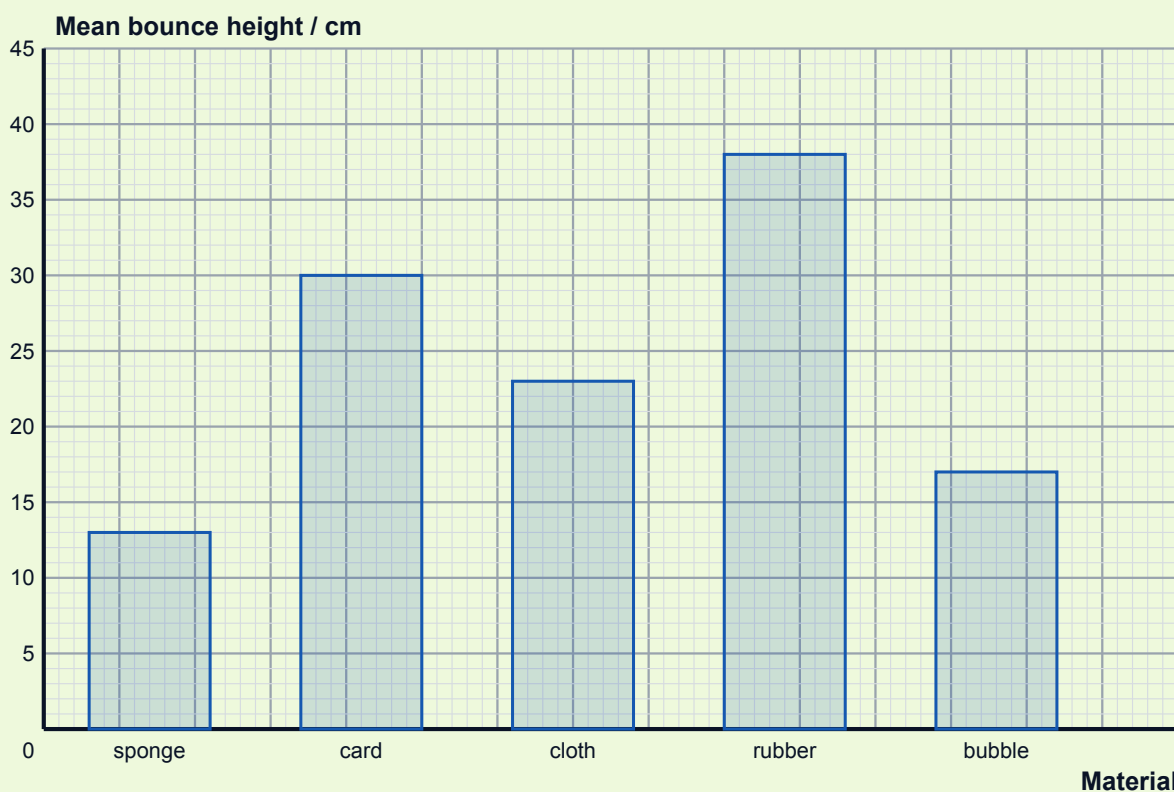
e.g. sponge: $(12 + 15 + 12) \div 3 = 39 \div 3 = 13$ cm

- 10 Did any reading make you look twice? Which one, and what did you do about it?

e.g. cardboard trial 3 (27 cm) was lower than 31 and 32, so we checked it and repeated the drop, recording both.



Material on the x-axis, mean bounce height on the y-axis. Choose your own scale. Add a title.

**CHECK YOUR BAR CHART**

✓

Title says what against what

☐

Material on the x-axis

☐

y-axis labelled with the unit, starting at 0

☐

Scale goes up in equal steps and uses most of the space

☐

Bars all the same width, with equal gaps

☐

Bar heights match the means, not trial 1

☐



- 1 Which material was the best shock absorber? Quote numbers from your results to back it up.

Sample: sponge, with the lowest mean bounce, 13 cm, compared with 38 cm for the rubber mat.

- 2 Why did you repeat each drop three times instead of once?

One drop could be a fluke. Repeats show how much readings vary, let an odd one be spotted, and give a mean that reduces the effect of random error.

- 3 Pin down the errors in *your* practical. Be specific: “human error” earns nothing.

Error	What went wrong in our practical	How we would reduce it
Random	judging the top of the bounce by eye	film it against the ruler and pause at the top
Systematic	0 cm on the ruler was not at the surface	check the zero before starting

- 4 Would ten more repeats fix the systematic error you named? ☐ yes ☒ no Explain.

No. A systematic error shifts every reading by the same amount, so the mean of more repeats is shifted too. The cause has to be found and fixed.

- 5 Explain what is wrong with what Leo says.

Leo

The rubber mat is the best shock absorber because it has the tallest bar.

The best shock absorber gives the lowest bounce, because it keeps the most energy.

The tallest bar shows the worst shock absorber.

- 6 **CHALLENGE** Another group tested the same materials and got quite different numbers. Give two reasons why, without either group having done anything wrong.

Any two: a different ball; a different drop height; a different thickness or sample of each material; a different surface under the materials.

- 7 **CHALLENGE** You test foam that is 1 cm, 2 cm, 3 cm and 4 cm thick instead of different materials. You would now need a **bar chart** **line graph** because thickness is **continuous** **categoric** What has changed?

The independent variable is now continuous (a number on a scale), not categoric.



AQA-STYLE

EXAM CORNER

Write in full sentences. Show every step of a calculation.

Get the marks: Show the sum, then divide by the number of trials.

- 11 A student drops a ball onto three surfaces. **[2 marks]**

Surface	Trial 1 / cm	Trial 2 / cm	Trial 3 / cm	Mean / cm
Carpet	14	16	15	15
Wood	42	40	44	42
Grass	25	31	22	26

Calculate the mean bounce height for wood. Write it in the table.

$$(42 + 40 + 44) \div 3 = 126 \div 3 (1) = 42 \text{ cm } (1)$$

- 12 Which surface absorbs the most energy from the ball? Give a reason. **[2 marks]**

Carpet (1); it has the lowest mean bounce height (1).

- 13 The student judged the bounce height by eye. Suggest **one** improvement to the method. **[1 mark]**

Film the bounce against the ruler and read the height from the paused video (1).



SUMMARY

- A categoric independent variable (material) → bar chart.
- Three trials for each value; mean = total ÷ number of trials.
- Units go in the table headings: "Trial 1 / cm".
- Bar chart: equal bars, equal gaps, y-axis from 0, bar = the mean.
- Name the error and match the fix; never just "human error".

COVER THE PAGE AND ANSWER

1 16 cm, 21 cm, 17 cm.

What is the mean?

.....

3 Why is the drop test shown on a bar chart?

.....

2 Does the best shock absorber give the highest or lowest bounce?

.....

4 What does the height of each bar show?

.....

I CAN...

calculate a mean from three trials



draw a results table with units in the headings



draw a bar chart a marker would accept



name a random and a systematic error and how to reduce each



HIGHER RAMP, FURTHER TRAVEL?

AQA Working scientifically WS 2.6, 3.1 · Physics and Combined Science

BIG QUESTION Can a few measurements tell you about heights you never tested?

BY THE END YOU CAN

- recognise a continuous independent variable and what follows from it
- record five values with three trials each and a mean
- choose a scale that uses most of the grid
- plot points accurately as small crosses
- label both axes with the quantity and the unit

continuous

line graph

scale

axis

plot

THE CASE

Nobody guesses a stunt jump. A stunt team does not find the right speed by trying the real jump. They run the car at several speeds, measure where it lands each time and plot the results. A line through the points gives the speed for a distance nobody has tested. One measurement on its own is not a pattern.

Five points and a line tell you about the gaps in between.



REMEMBER

DO NOW

From earlier lessons. No notes!

1

Calculate the mean of 51 cm, 53 cm and 58 cm.

$$162 \div 3 = 54 \text{ cm}$$

2

Material is categoric (continuous / categoric), so the drop test needs a bar chart.

categoric

3

Each bar in a bar chart shows the mean (trial 1 / the mean / the largest reading).

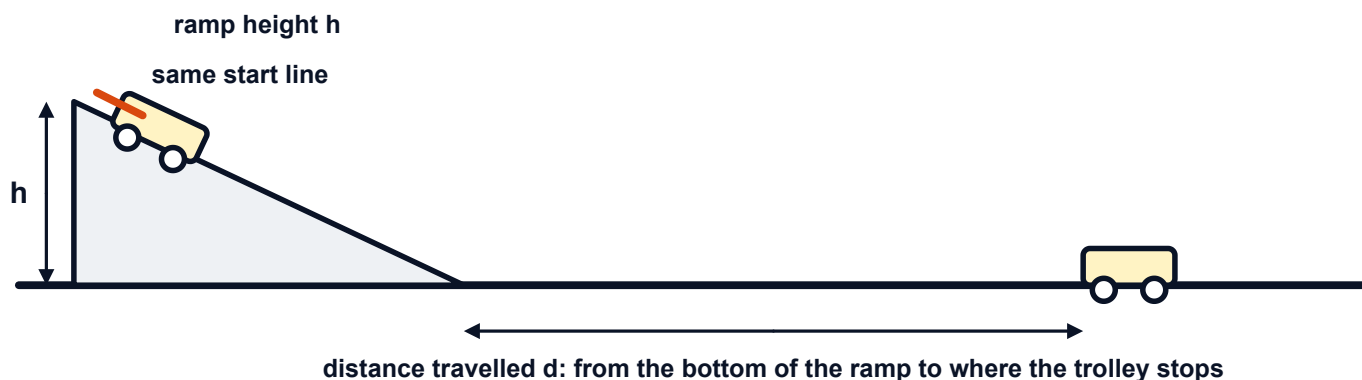
the mean



EXPLAIN

MAKE A PATTERN VISIBLE

The question: **How does the height of a ramp affect the distance a trolley travels?** Ramp height is a number on a scale, so it is continuous, and the results go on a line graph.



VARIABLE	IN THE RAMP PRACTICAL
Independent	ramp height / cm (continuous)
Dependent	distance travelled / cm, from the bottom of the ramp to where the trolley stops
Control	same trolley; same ramp; same start line; same floor; released with no push

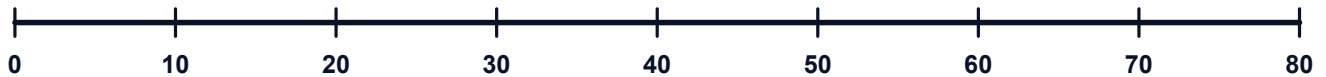
! Why five heights? Two points can always be joined by a straight line, so two tell you nothing about the shape of the pattern. Five evenly spaced heights, 5 cm to 25 cm, show whether it is straight or curved. The **range** of ramp heights is from 5 cm to 25 cm.

CHOOSE THE SCALE FIRST

- 1 Find the largest value that has to fit on the axis.
- 2 Count the big squares along that axis.
- 3 Divide, then round **up** to 1, 2, 5, 10, 20 or 50 per big square.
- 4 Check that the largest value still fits.

WORKED EXAMPLE		YOUR TURN	
Largest mean: 80 cm. There are 9 big squares up the y-axis.		Largest value: 45 cm. There are 10 big squares along the axis.	
DIVIDE	$80 \div 9 \approx 8.9$ cm per big square	DIVIDE	$45 \div 10 = 4.5$ cm per big square
ROUND UP	10 cm per big square	ROUND UP	5 cm per big square
CHECK	$9 \times 10 = 90$ cm, more than 80 cm ✓	CHECK	$10 \times 5 = 50$ cm, more than 45 cm ✓

A good scale: equal steps of 10



Not a scale: the results written along the axis



Why 1, 2, 5 or 10? A big square is ten small squares. If a big square is worth 10, each small square is worth 1; if it is worth 5, each is 0.5. If a big square is worth 3, each small square is 0.3, and plotting 7 means counting $23\frac{1}{3}$ small squares. Fill the grid: on a bigger graph, a small slip of the pencil is a smaller error.

■ PLOT PRECISELY

- Independent variable on the x-axis, dependent variable on the y-axis.
- Label each axis with the quantity and the unit: "Ramp height / cm".
- Plot the **means**, as small crosses: the centre of a × is an exact point; a blob covers several small squares.
- No bars and no dot-to-dot. The line comes in Lesson 5.
- Read each cross back off the graph and compare it with the table. It catches most plotting slips.



INVESTIGATE THE RAMP

Record each number the moment you read it:
redoing a height because nobody wrote down trial 2
is the biggest time-waster.

Independent variable	ramp height / cm
Dependent variable	distance travelled / cm
Continuous or categoric?	☒ continuous ☐ categoric
Graph type	☒ line graph ☐ bar chart

- 5 Four control variables. Tick each one off as your group agrees on it.

**Same trolley; same start line on the ramp; same floor surface; release with no push
(also: same ramp).**

- 1 Set the ramp to 5 cm.
- 2 Put the trolley at the marked start line.
- 3 Release it. Do not push: a push adds energy you cannot measure or repeat.
- 4 Measure the distance from the bottom of the ramp to where the trolley stops.
- 5 Do three trials, then change the height: 10, 15, 20 and 25 cm.

STAY SAFE

- Check the ramp is stable before every release.
- Never aim the trolley at a person; keep the lane clear of bags and stools.
- Collect the trolley by hand: do not chase it.

■ RESULTS

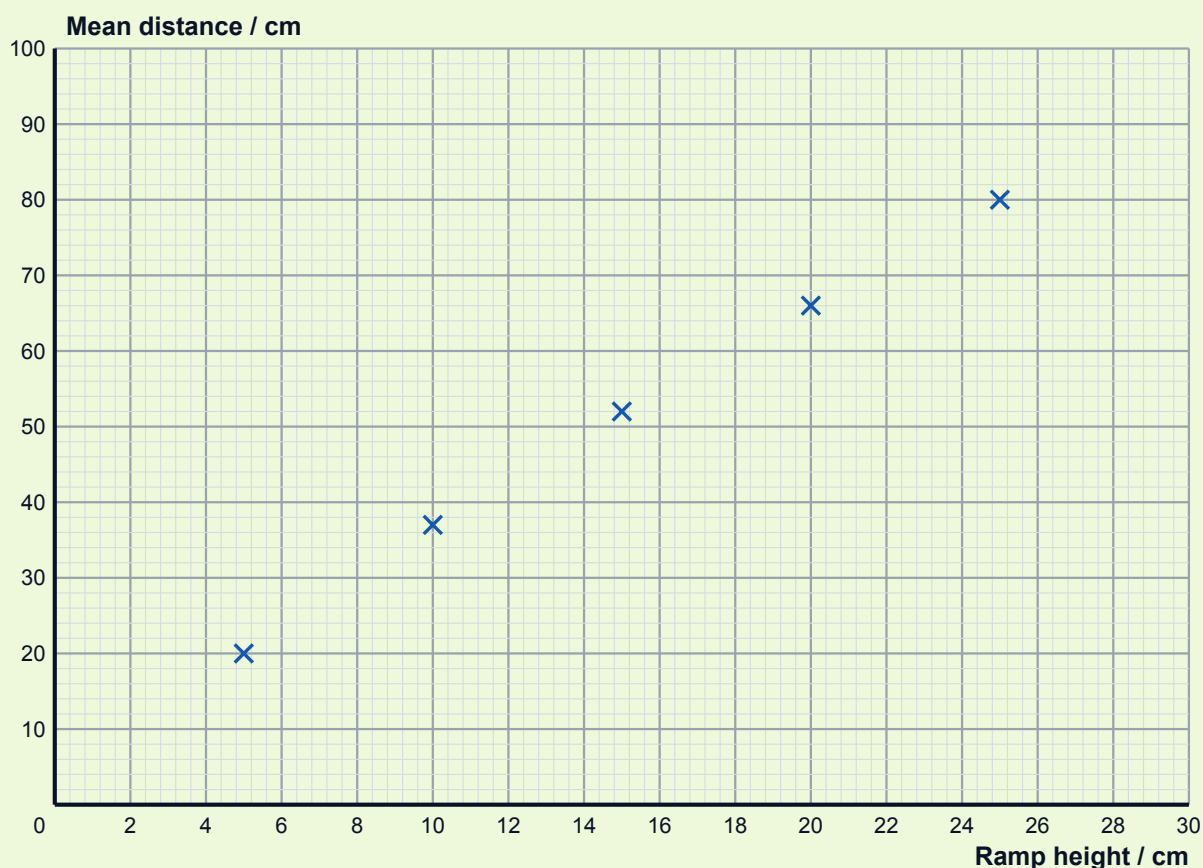
Ramp height / cm	Distance 1 / cm	Distance 2 / cm	Distance 3 / cm	Mean distance / cm
5	18	21	21	20
10	36	39	36	37
15	51	54	51	52
20	64	69	65	66
25	81	78	81	80

6 Choose your scales before you plot. You need your largest mean first.

My largest mean	80 cm (sample)
y-axis: each big square is worth	<u>10</u> (1 / 2 / 5 / 10 / 20) cm
x-axis: each big square is worth	<u>2</u> (1 / 2 / 5 / 10) cm



Ramp height on the x-axis, mean distance on the y-axis. Plot each mean as a small ×. Label both axes with units, and add a title.



■ MISTAKE HUNT

CHECK YOURS, THEN SWAP WITH A PARTNER	MINE	PARTNER'S
Units missing from one or both axes	☐	☐
Scale nobody can read, or not in equal steps	☐	☐
Graph crammed into one corner of the grid	☐	☐
Dependent variable on the x-axis by mistake	☐	☐
Bars drawn instead of plotted points	☐	☐
Points joined dot-to-dot	☐	☐

7 One thing my partner's graph does better than mine:

Open, e.g. "their scale fills the whole grid".



- 1 Draw a ring around the correct answer in each row.

Ramp height goes on the

x-axis	y-axis
---------------	--------

The mean distance goes on the

x-axis	y-axis
--------	---------------

A line graph is right because ramp height is

continuous	categoric
-------------------	-----------

- 2 Choose the best value for each big square. Draw a ring around one value in each row.

Largest value 64 cm, 8 big squares:

5 cm	8 cm	10 cm
------	------	--------------

Largest value 3.6 s, 8 big squares:

0.4 s	0.45 s	0.5 s
-------	--------	--------------

Largest value 170 g, 10 big squares:

17 g	20 g	50 g
------	-------------	------

- 3 Explain what is wrong with Mia's axis.



I labelled my y-axis 20, 37, 52, 66, 80, the same as my results.

An axis must go up in equal steps (e.g. 0, 10, 20 ...). Mia's steps are 17, 15, 14, 14, so the points' positions mean nothing.

- 4 Look at the sample means: 20, 37, 52, 66, 80 cm. For each extra 5 cm of height, the distance goes up by 17, 15, 14 and then 14 cm. Will the graph be a straight line or a curve? Commit to an answer and give your reason.

A gentle curve: the distance keeps rising, but by slightly smaller steps each time.



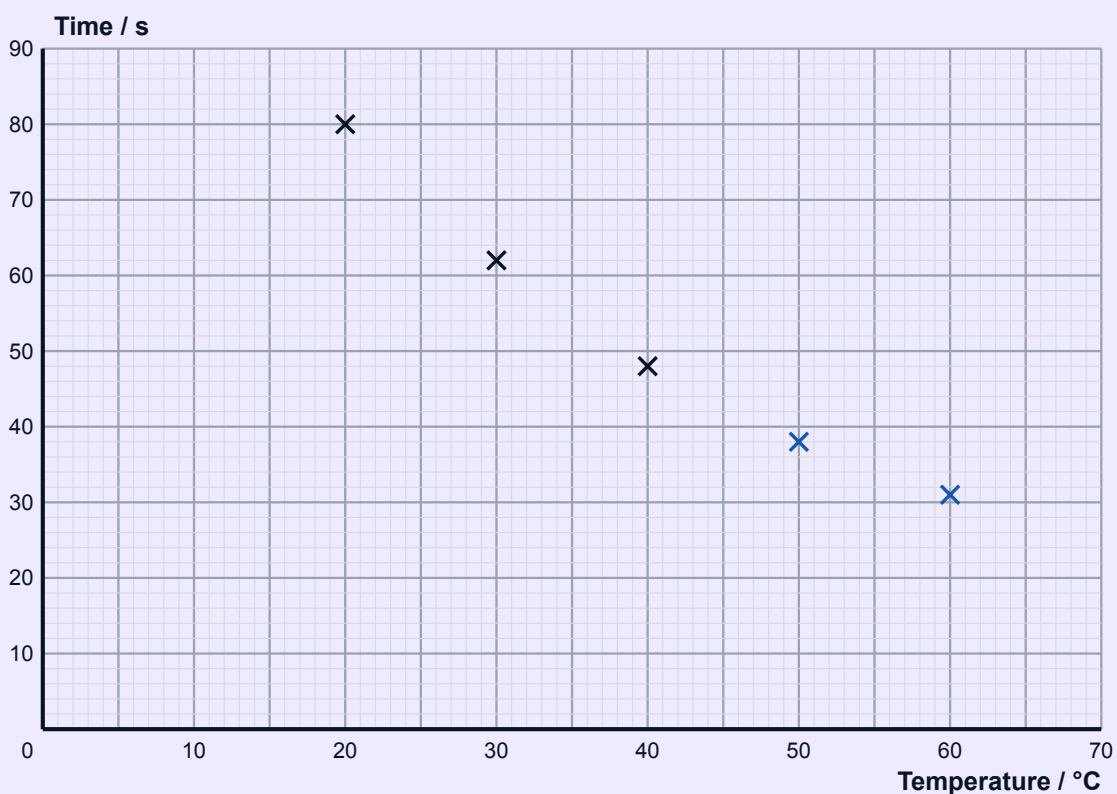
Get the marks: Plot each point as a small × to within half a small square.

8

A student measures how the temperature of water affects the time for sugar to dissolve. Three points are plotted.

[2 marks]

Temperature / °C	20	30	40	50	60
Time / s	80	62	48	38	31



Plot the results for 50 °C and 60 °C.

(50, 38) (1); (60, 31) (1)

9

Explain why the temperature is plotted on the x-axis.

[1 mark]

It is the independent variable (the one the student changes) (1).

10

Why is a line graph the right choice for these results?

[1 mark]

Temperature is continuous (1).

**SUMMARY**

- Continuous independent variable (ramp height) → line graph.
- Five values, evenly spaced, show the shape of a pattern.
- Scale: largest value ÷ big squares, rounded up to 1, 2, 5, 10, 20 or 50.
- Independent on the x-axis, dependent on the y-axis, units on both.
- Plot the means as small crosses; no dot-to-dot.

COVER THE PAGE AND ANSWER

1 What goes on the x-axis?

.....

3 Why plot crosses, not blobs?

.....

2 Largest value 45 cm, 10 big squares. Value of each square?

.....

4 The trolley veers sideways on some runs. What kind of error?

.....

I CAN...

choose a scale that fills the grid



label axes with quantity and unit



plot means accurately as small crosses



explain why ramp height needs a line graph



THE POINT THAT DOES NOT FIT

AQA Working scientifically WS 3.5, 3.6 · Physics and Combined Science

BIG QUESTION One point is far from all the others. Do you delete it?

BY THE END YOU CAN

- draw a best-fit line, straight or curved, that shows the trend
- explain why dot-to-dot is wrong for measured data
- identify a possible anomalous result and say what to do about it
- write a conclusion supported by numbers

best-fit line

trend

anomalous result

conclusion

correlation

THE CASE (1985)

The readings too strange to believe.

British Antarctic Survey scientists found, from measurements on the ground, that the ozone above Antarctica fell sharply every spring. A satellite had recorded the same very low values, but its software flagged them as readings it could not trust. The odd values were not thrown away, and not believed straight away either: they were checked. The ozone hole was real.

An odd result is a question, not rubbish.



REMEMBER

DO NOW

From earlier lessons. No notes!

1

The independent variable goes on the x-axis (x-axis / y-axis).

x-axis

2

Largest value 64 cm, 8 big squares. Each big square should be worth 10 cm (8 cm / 10 cm / 15 cm).

10 cm ($64 \div 8 = 8$, rounded up)

3

Why plot small crosses instead of blobs?

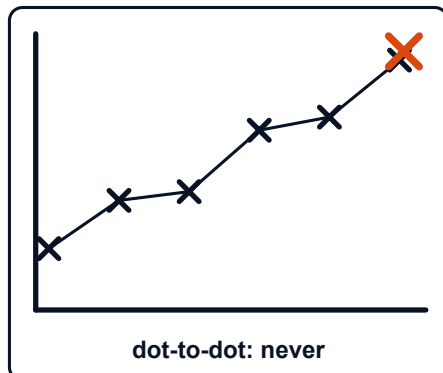
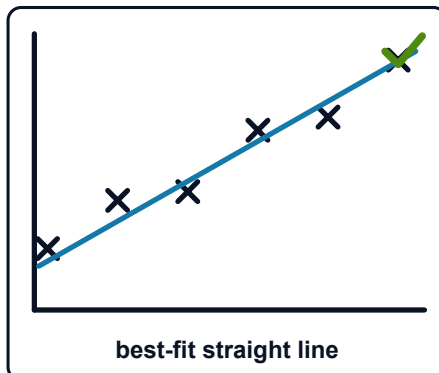
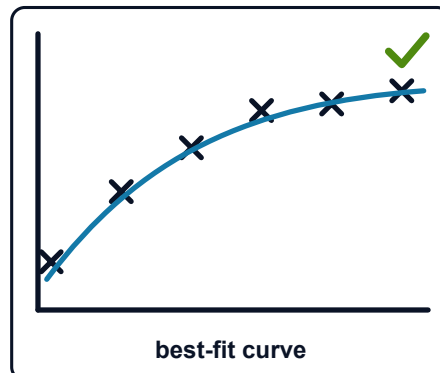
The centre of a cross

marks an exact point; a

blob covers several small squares.



SHOW THE TREND WITH A BEST-FIT LINE



DO	DO NOT
Draw one thin, smooth line: straight (with a ruler) or curved	Zig-zag from point to point
Balance the points: about as many above the line as below	Force the line through the first and last points
Draw it across the range of your data	Let an anomalous result drag the line towards it

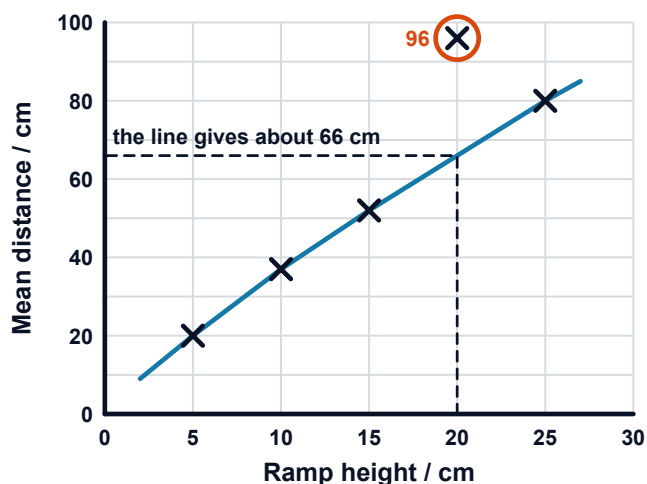
Why may a best-fit line touch none of the points? Every measurement has some uncertainty, so each point is a little off, some high and some low. The line averages them all at once, the way a mean averages three trials. A dot-to-dot line claims every reading is exactly right, which you proved untrue in Lesson 1.

Straight or curved? Hold a ruler along the points. If they sit either side of it at random, draw a straight line. If they are above it in the middle and below it at both ends, draw a curve.

SPOT THE ANOMALOUS RESULT

Ramp height / cm	Mean distance / cm
5	20
10	37
15	52
20	96
25	80

An **anomalous result** does not fit the pattern of the others. 96 cm is about 30 cm above the line, and it says the trolley went further from a 20 cm ramp than from a 25 cm ramp.



WHAT TO DO WITH AN ANOMALOUS RESULT

- 1 **Spot it:** it is far from the trend.
- 2 **Check** the recording, the arithmetic and the plotting. Was 66 written as 96?
- 3 **Check** the method and the equipment. Was the trolley pushed? Look at the three trials: often only one is wrong.
- 4 **Repeat** the measurement if you can. Plot as you go, so you can repeat while the equipment is still set up.
- 5 **Mistake found:** correct it and use the corrected value. **No cause found:** keep it, circle it on the graph, report it, and leave it out of the best-fit line.



Never silently delete evidence. The odd point might be real, as the ozone readings were. And if you remove every point that does not fit your line, the line proves nothing.

A CONCLUSION NEEDS A NUMBER

- Name both variables, and give the direction: increase or decrease.
- Quote two values with units from your results.
- Say whether the pattern is a straight line or a curve.
- Name any possible anomalous result, or say there is none.

EXAMPLE CONCLUSION

As the ramp height increased, the mean distance increased: at 5 cm it was 20 cm and at 25 cm it was 80 cm. The height went up 5 times but the distance only 4 times, so the distance is **not directly proportional** to the height; the graph is a gentle curve. Both increase together: a **positive correlation**. Possible anomalous result: 96 cm at 20 cm, far above the line.

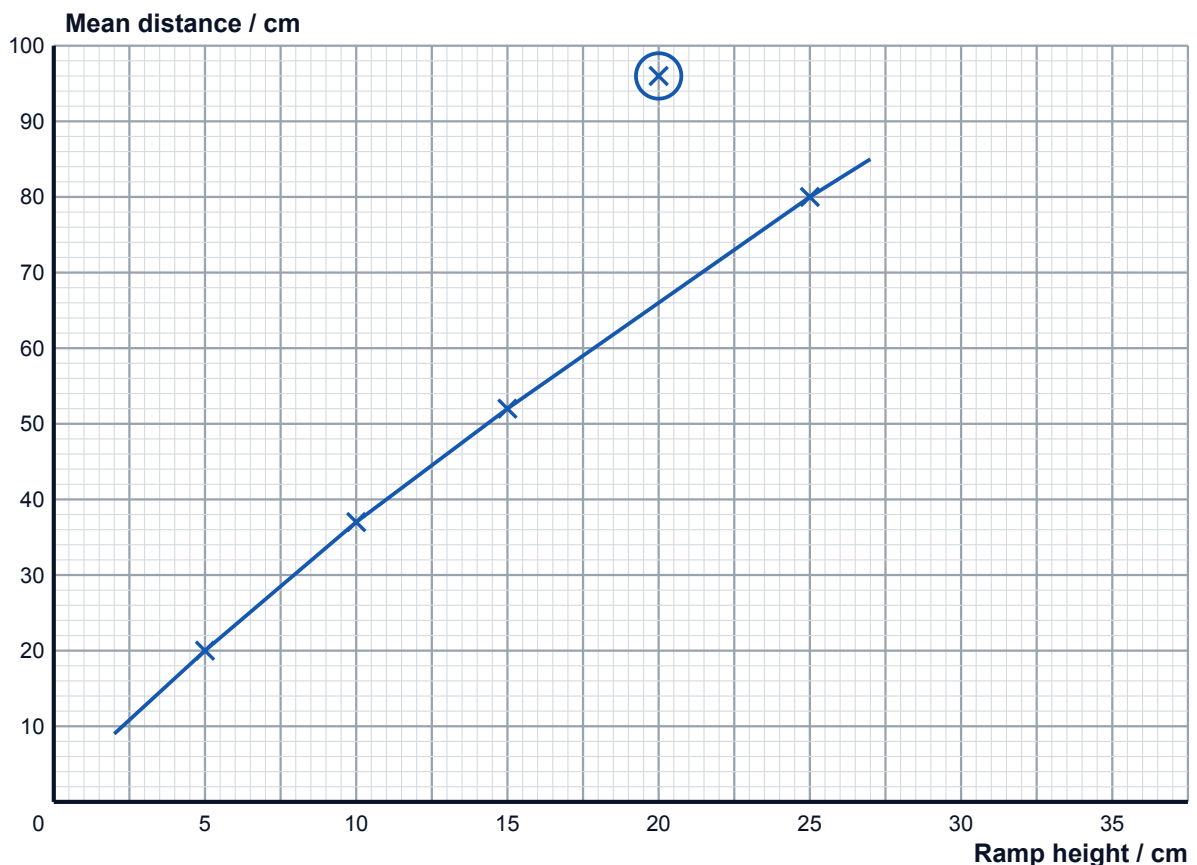
Where the model breaks: Directly proportional means a straight line through the origin: double one quantity and the other doubles.



PRACTISE

BEST FIT AND ODD POINTS

- 1 Another class got these means in the ramp practical: 5 cm → 20 cm, 10 cm → 37 cm, 15 cm → 52 cm, 20 cm → 96 cm, 25 cm → 80 cm. Plot them and draw a best-fit line through the trend.



a The anomalous result is at

5 cm	10 cm	15 cm	20 cm	25 cm
------	-------	-------	-------	-------

b Your best-fit line gives a distance at 20 cm of about 66 (50 / 66 / 80 / 96) cm.

2 Look again at the anomalous result at 20 cm.

a Should the class delete it? Write what they should do first, and why.

No. First check how it was recorded and calculated (66 written as 96?) and check the method; repeat it if possible. It might be real, so it is not deleted without a reason.

b Give two things that could cause a reading like this in the ramp practical.

Any two: the trolley was pushed; it was released from higher up the ramp; the ramp was set to the wrong height; 66 was written down as 96.

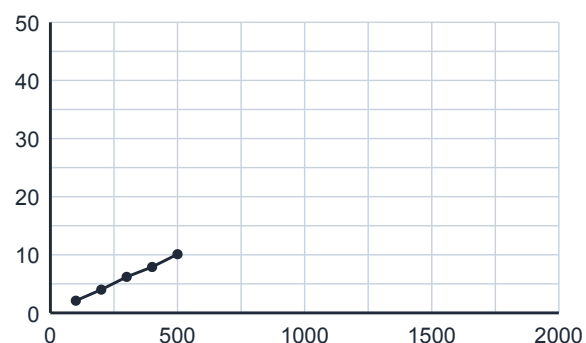
3 What is a dot-to-dot line claiming about the measurements? Why is that claim untrue?

It claims every measurement is exactly right. Every measurement has some uncertainty (random error), so the points scatter around the true pattern.

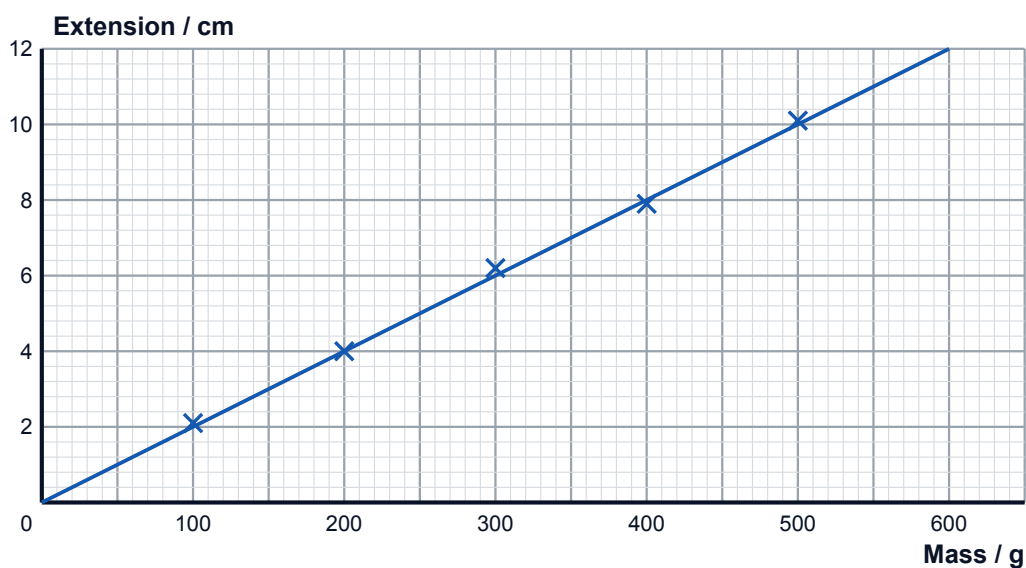
- 4 **CHALLENGE** Mark someone else's graph. A student plotted the spring results below. Tick the **four** problems with the graph.

PROBLEM	✓
Axes not labelled	☒
No units	☒
Points joined dot-to-dot	☒
Scale squashes the data into one corner	☒
Too few points	☐
Dependent variable on the x-axis	☐

Mass / g	Extension / cm
100	2.1
200	4.0
300	6.2
400	7.9
500	10.1



Redraw the graph properly, with a title, labelled axes, a sensible scale and a best-fit line.



- 5 Which conclusion is best? Tick **one** box.

- ☐ It went up.
- ☐ The distance increased.
- ☒ As the ramp height increased, the mean distance increased, from 20 cm at 5 cm to 80 cm at 25 cm.
- ☐ The results were good.



Add the best-fit line. Circle any point that is far from it and write a short note beside it. If there are none, write “no anomalous results: all points lie close to the line”. Saying so is worth marks.

BEFORE YOU CALL IT FINISHED

✓

Title included	☐
x-axis labelled with the unit	☐
y-axis labelled with the unit	☐
Sensible scale, using most of the grid	☐
Points plotted accurately as small crosses	☐
One best-fit line, not dot-to-dot	☐
Anomalous results circled and noted, or “none” written	☐

■ WRITE THE CONCLUSION

The trend: as the ramp height increased, the distance...	<div><div>increased</div><div>decreased</div><div>stayed the same</div></div>
Evidence: two values from my results, with units	at 5 cm, 20 cm; at 25 cm, 80 cm (sample)
The shape of my graph	<div><div>straight line</div><div>curve</div></div>
A possible source of random error	judging where the trolley stopped; the trolley veering sideways
Possible anomalous result (or “none”), and why	none: all points lie close to the line (sample)

PEER REVIEW

Swap booklets. Check your partner's graph against the list above, then give one specific improvement: not "make it neater".

Reviewed by	
Strongest thing about this graph	
One specific improvement	e.g. "your x-axis goes up in 3s: use 5s"



AQA-STYLE

EXAM CORNER

Write in full sentences. Show every step of a calculation.

Get the marks: A best-fit line shows the trend; it does not have to pass through any point.

- 6 A student's best-fit line passes through none of the plotted points. A friend [2 marks] says the line must be wrong. Is the friend right? Explain.

No: a best-fit line shows the overall trend (1); the points should be balanced on either side, and it need not touch any of them (1).

- 7 Give **two** reasons why an anomalous result should not simply be deleted. [2 marks]

It might be a real effect (1); it should be checked and repeated first / deleting inconvenient data is dishonest (1).

TAKE IT HOME

- 8 Find a graph outside school: a news site, a sports app or an advert. Run it through the graph checklist on the last page.

Where it came from, and what it shows	
Two things it does well	
One thing that would lose marks in Year 9	e.g. no units; a y-axis that does not start at zero; uneven scale

**SUMMARY**

- A best-fit line shows the trend: one smooth line, straight or curved, points balanced either side.
- Dot-to-dot claims every reading is exact: never use it for measured data.
- Anomalous result: check, repeat, then correct it or keep and circle it. Never silently delete.
- A conclusion names both variables, the direction, and quotes values with units.

COVER THE PAGE AND ANSWER**1** What is a best-fit line?

.....

3 What is an anomalous result?

.....

2 Why avoid dot-to-dot?

.....

4 What is the first step with an anomalous result?

.....

I CAN...

draw a best-fit line, straight or curved



spot an anomalous result and say what to do about it



write a conclusion with numbers as evidence



KEY WORDS

Learn the meaning and the spelling. In exams, precise words earn marks: say “random error”, never “human error”.

Accurate [L1]: Close to the true value

Precise [L1]: Repeat readings are close to each other: little spread about the mean

Trial [L1]: One repeat of a measurement

Mean [L1]: The total of the trials divided by the number of trials

Uncertainty [L1]: The interval within which the true value can be expected to lie. From repeats:
 $(\text{largest} - \text{smallest}) \div 2$

Range [L1]: The maximum and minimum values of the independent or dependent variables, stated “from ... to ...”

Resolution [L1]: The smallest change a measuring instrument can detect

Random error [L1]: Unpredictable spread between repeats. Repeats and a mean reduce it

Systematic error [L1]: An error that shifts every reading by the same amount in the same direction. Repeats do not fix it

Zero error [L1]: An instrument reads a value when it should read zero: a systematic error

Repeatable [L1]: The same person, method and equipment give similar results again

Reproducible [L1]: Another person, or different equipment or method, gives similar results

Independent variable [L2]: The one thing you change

Dependent variable [L2]: The thing you measure

Control variable [L2]: Something you keep the same so it cannot affect the result

Fair test [L2]: Only the independent variable changes; all the control variables are kept the same

Continuous data [L2]: Numbers that can take any value on a scale, such as length, time or mass

Categoric data [L2]: Names or groups, such as material, colour or brand

Line graph [L2]: The graph to use when the independent variable is continuous

Bar chart [L2]: The graph to use when the independent variable is categoric

Scale [L4]: The numbers along an axis, going up in equal steps

Best-fit line [L5]: One straight or curved line showing the overall trend, with points balanced on either side

Anomalous result [L5]: A result that does not fit the pattern of the others

Positive correlation [L5]: As one variable increases, the other increases too

Directly proportional [L5]: Double one, and the other doubles: a straight line through the origin

Conclusion [L5]: What the results show overall, with numbers as evidence

■ PHRASES THAT PICK UP MARKS

INSTEAD OF WRITING...	WRITE...
"It was human error."	"Reaction time when starting the stopwatch caused random error."
"The results were good."	"The repeats were close together, so the data is precise."
"It's a bar chart."	"A bar chart was used because material type is categoric."
"Keep it a fair test."	"Use the same trolley and the same start line each time."
"We did it three times."	"Three trials were taken at each value so that a mean could be calculated."
"It went up."	"As the ramp height increased, the mean distance increased from 20 cm to 80 cm."
"One result was weird."	"The value at 20 cm is a possible anomalous result: it is far above the trend."

PROGRESS TRACKER

Colour one circle for each statement: **red** = not yet, **amber** = getting there, **green** = I can do this without help. Revisit your reds first.

I CAN...	R / A / G
03: The drop test	
calculate a mean from three trials	  
draw a results table with units in the headings	  
draw a bar chart a marker would accept	  
name a random and a systematic error and how to reduce each	  
04: Higher ramp, further travel?	
choose a scale that fills the grid	  
label axes with quantity and unit	  
plot means accurately as small crosses	  
explain why ramp height needs a line graph	  
05: The point that does not fit	
draw a best-fit line, straight or curved	  
spot an anomalous result and say what to do about it	  
write a conclusion with numbers as evidence	  



One habit worth building. When something in your results looks wrong, the useful question is never “can I ignore that?” It is “why did that happen?”

THE WHOLE UNIT IN ONE SENTENCE

Measure it more than once, be honest about the doubt, show the pattern clearly, and let the evidence decide.

QUICK ANSWERS

Answers to the “Do now” and “Cover the page” questions, so you can check yourself when revising. Answers to the longer questions are in your teacher's answer edition.

LESSON 3: THE DROP TEST

DO NOW

1. a bar chart
2. independent
3. systematic (a zero error)

COVER THE PAGE

1. $54 \div 3 = 18$ cm
2. The lowest.
3. Material is categoric.
4. The mean, not one trial.

LESSON 4: HIGHER RAMP, FURTHER TRAVEL?

DO NOW

1. $162 \div 3 = 54$ cm
2. categoric
3. the mean

COVER THE PAGE

1. The independent variable (ramp height / cm).
2. $4.5 \rightarrow$ round up to 5 cm.
3. The centre of a cross is an exact point.
4. Random; use a marked lane.

LESSON 5: THE POINT THAT DOES NOT FIT

DO NOW

1. x-axis
2. 10 cm ($64 \div 8 = 8$, rounded up)
3. The centre of a cross marks an exact point; a blob covers several small squares.

COVER THE PAGE

1. One smooth line showing the overall trend of the data.
2. It claims every reading is exact.
3. A result that does not fit the pattern.
4. Check the recording and plotting, then repeat it.

THE PHYSICIST'S TOOLKIT

Everything you need for the whole unit, on one page. Fold the corner: you will come back to it.

THE THREE VARIABLES

Independent the one thing you change

Dependent the thing you measure

Control everything you keep the same

Ask: "How does *independent* affect *dependent*?"

TWO KINDS OF DATA

Continuous any value on a scale: length, time, mass → **line graph**

Categoric names or groups: material, colour → **bar chart**

Test: is there a value in between?

THE TWO CALCULATIONS

mean = total of the trials ÷ number of trials

uncertainty = (largest – smallest) ÷ 2

Write the result as mean ± uncertainty, e.g. 1.22 s ± 0.03 s.

PRECISE OR ACCURATE?

Precise repeats close *to each other*

Accurate close *to the true value*

Resolution the smallest change an instrument can detect

You can be precise and still wrong.

THE TWO ERRORS

Random scatters repeats both ways. **Repeat and take a mean.**

Systematic shifts every reading the same way. **Find the cause; repeats do not help.**

CHOOSING A SCALE

Largest value ÷ number of big squares, then round **up** to 1, 2, 5, 10, 20 or 50 per big square. Equal steps. Use most of the grid.

ANOMALOUS RESULTS

Spot it (far from the trend) → **check** the recording, maths and method → **repeat** if you can. Mistake found: correct it. No cause: keep it, circle it, report it, and leave it out of the best-fit line. Never delete it silently.

CONCLUSION AND EVALUATION

Conclude: "As X increased, Y increased", with two values and units. Straight or curved?

Evaluate: a strength, a weakness, a named error, and an improvement that fixes it. Never just "human error".

GRAPH CHECKLIST

- Title: what against what
- Independent variable on the x-axis
- Both axes labelled, with units: "Ramp height / cm"
- Scale in equal steps that fills the grid
- Means plotted as small, accurate crosses
- One best-fit line: never dot-to-dot
- Bar chart: equal bars, equal gaps, axis from 0
- Anomalous results circled, or "none"

THE RULE THAT DECIDES YOUR GRAPH

Continuous independent variable → **line graph**. **Categoric independent variable** → **bar chart**.

It depends on what you *changed*, not on what you measured.