NATURE OF SCIENCE

Measurements, tables and graphs

Teacher review edition. Ask your teacher if anything is unclear.

How do we turn measurements into a clear conclusion?

What you will learn

- Record measurements with units and calculate a mean.
- Choose a graph and describe its pattern.
- Explain the difference between accuracy and precision.
- Identify an unusual result and suggest a useful check.

Make useful measurements

> **Repeat**
> Another measurement made under the same conditions.

A measurement needs a number and a unit: write 12 cm, not just 12.

- Choose suitable equipment: a ruler for length, a balance for mass.
- Check that the instrument reads zero when it should.
- Read a scale with your eye level with the mark.
- Record only the detail the instrument can reasonably show.

Accuracy and precision

> **Accuracy**
> How close a measurement is to the accepted value.
>
> **Precision**
> How close repeated measurements are to each other.

Close readings are not always accurate readings.

- Accuracy: how close a reading is to the accepted value.
- Precision: how close repeated readings are to one another.
- A balance that reads 2 g when empty may give similar readings that are all 2 g too high.
- Taking a mean does not remove this zero error. Zero the balance or correct for the error.

Use a results table

Prepare your results table before starting.

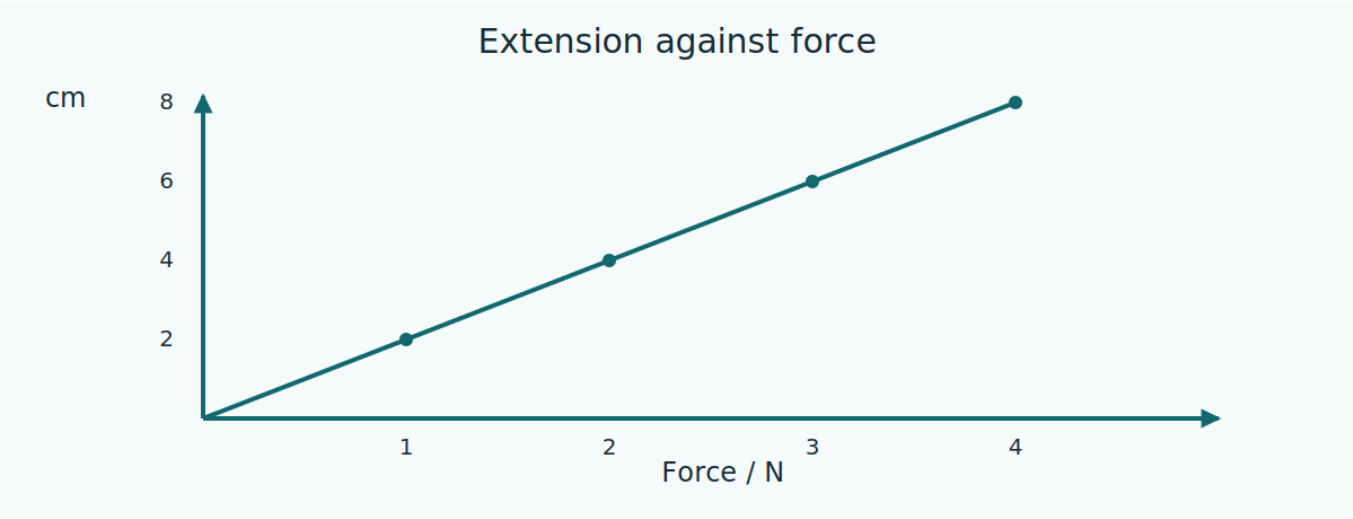
- Put quantities and units in the headings: for example, Force (N) and Extension (cm).

- Use separate columns for repeated readings.
- Mean: add the readings, then divide by the number of readings.
- Range: subtract the smallest reading from the largest. A larger range means more spread.

Choose and draw a graph

A graph makes patterns easier to see.

- Use a bar chart for categories, such as different materials.
- Use a scatter or line graph to compare two numerical quantities.
- Usually, put the changed variable on the horizontal axis and the measured variable on the vertical axis.
- Label each axis with its quantity and unit. Use an even scale that fills most of the graph.
- A best-fit line shows the pattern. It may be straight or curved and need not pass through every point or through zero.



A line graph places the changed variable, force, on the horizontal axis and the measured extension on the vertical axis. These are example values.

Find the gradient

Graph gradient
The change up a graph divided by the change across it.

The gradient tells us how steep a graph is.

$$\text{gradient} = \frac{\text{change on the vertical axis}}{\text{change on the horizontal axis}}$$

- Choose two widely separated points on the straight line of best fit.
- Find the vertical change and the horizontal change between them.
- Gradient = vertical change ÷ horizontal change.
- For extension against force, 2 cm per newton means 2 cm of extra extension for each extra newton, within the tested range.

Investigate unusual results

Anomaly
A result that does not fit the overall pattern.

- Check the written record and equipment, then repeat the measurement.
- Keep the original result and explain any decision to leave it out of a calculation.
- Use the results to answer the investigation question.
- State the tested range: a spring's behaviour from 1 N to 3 N does not tell us what happens under a much larger load.

A pattern does not always show a cause

Correlation
A link between two quantities in the data. This alone does not prove that one causes the other.

- A correlation alone does not prove that one quantity causes the other.
- Ice-cream sales and swimming both increase in warm weather.
- Warm weather helps explain both patterns; buying ice cream does not cause someone to swim.

Worked examples

A spring extends 2 cm under a force of 1 N and 6 cm under a force of 3 N. Find the gradient of its extension–force graph.

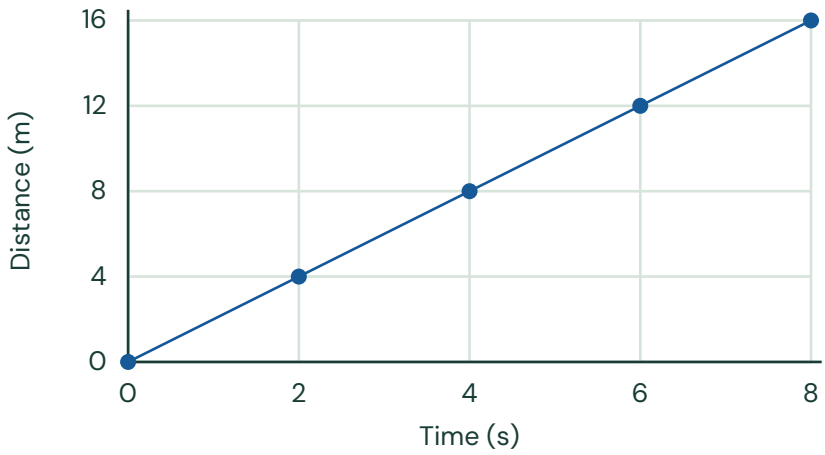
Work through it

1. The vertical change is 6 − 2 = 4 cm.
2. The horizontal change is 3 − 1 = 2 N.
3. Gradient = 4 ÷ 2 = 2 cm per newton. The spring extends by 2 cm for each extra newton in this range.

$$\text{gradient} = \frac{6 - 2}{3 - 1} = 2 \text{ cm per N}$$

Use a graph as evidence

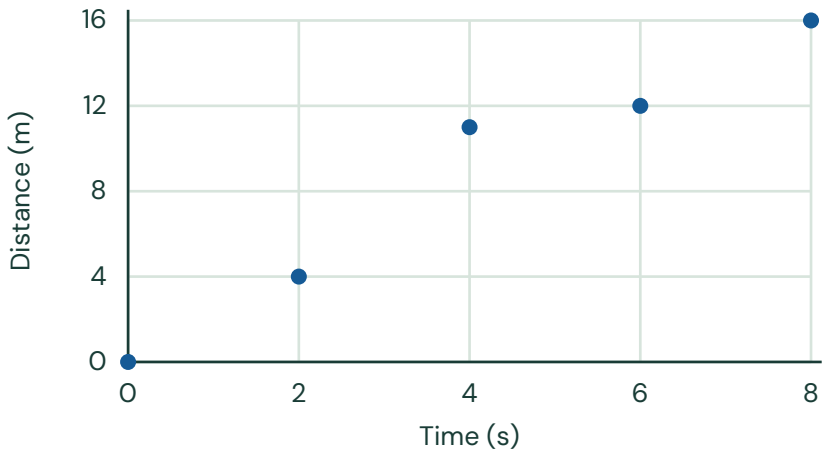
A student recorded the distance a trolley travelled from its start. Read the graph before looking at the explanation.



Working	Why?
Read the axes: time (s) and distance (m).	The horizontal axis tells you when. The vertical axis tells you how far.
At 2 s the distance was 4 m; at 6 s it was 12 m.	Quote values with their units so someone else can check your claim.
The distance increases by 4 m every 2 s.	The equal rises over equal times support the conclusion that the trolley travelled at a steady speed.

Try it yourself

On the second graph, which result does not fit the pattern? What should you do next?



Check your answer: At 4 s the recorded distance is 11 m; the other readings suggest about 8 m. Check the record and repeat the measurement or trial under the same conditions. Don't discard a result just because it doesn't fit.

Common mistakes

Common mistake: All the readings agree, so they must be accurate.

Remember: They are precise, but they could all share an error. A balance with a zero error can give similar readings that are all too high.

Common mistake: A line of best fit must join every point.

Remember: It shows the overall pattern. Points may lie on either side; do not force the line through every point or through zero.

Answering questions

- For a gradient, use two well-separated points on the best-fit line. Show vertical change divided by horizontal change and include the units.
- When describing a pattern, name both quantities and use values from the results. Then mention any anomaly or limit to the range tested.

Try an investigation

Plot the spring data supplied by your teacher. Label the axes, draw a line of best fit and identify any unusual point. Explain which measurement you would repeat and why.

Plan, record and review

- Question and prediction: What are you testing, and what do you think will happen? Give a reason.
- Change, measure, keep the same: What will you deliberately change? What will you measure, and in what units? What stays the same to make it a fair test? For an observation, say what you will record consistently instead.
- Record and look for a pattern: Use a table with headings and units. Look for a pattern or a result that does not fit.
- Conclude from evidence: Answer your question using a result or observation. Say if the evidence is unclear.
- Improve the investigation: What would you repeat or change, and how would that make the evidence better?

Do practical work with your teacher and follow the laboratory safety instructions.