

Practical graphs errors and evidence

AQA GCSE Combined Science Trilogy 8464 and Separate Physics 8463 | Papers 1 and 2 | Both tiers

Worked answers and marking guidance | 27 parts | 52 marks

Skills practised and specification contexts

Both courses: WS 2.2, 2.6, 2.7 and WS 3.1–3.7: measurements, graphs and evidence
8463 4.2.1.3 / 8464 6.2.1.3: resistance from current and potential difference
8463 4.5.3 / 8464 6.5.3: spring compression, proportionality and $F = kx$
8463 4.3.1.1 / 8464 6.3.1.1: density and displacement measurements
8463 4.1.1.3 / 8464 6.1.1.3: specific heat capacity and thermal measurements

A school laboratory reviews test data for a model delivery trolley: its spring buffer, chassis material and parcel-heater circuit. Decide which measurements and conclusions can be trusted, and how the tests should be improved.

Original PhysicsUK practice, not an official AQA resource. Credit equivalent reasoning and consistent error carried forward (ECF). All contexts use shared GCSE content. Figure 2 is deliberately flawed; its teacher version supplies the corrections.

1 Zero checks on the heater circuit

A digital ammeter has adjacent display values of 0.23 A and 0.24 A. When disconnected, it reads +0.04 A. Assume this same positive offset is added to every current reading. The voltmeter is correctly zeroed.

1(a) State the resolution of the ammeter display. **[1 mark]**

Answer / mark points: 0.01 A. [1] Resolution is the smallest change displayed, not the full current reading.

1(b) Name the error shown by the disconnected ammeter. **[1 mark]**

Answer / mark points: A zero error. [1] It is a systematic error: every reading has the same positive offset. Accept systematic error.

1(c) During a test, 4.0 V is measured across the heater and the ammeter reads 0.24 A. Correct the current reading, then calculate the heater's resistance using $R = V / I$. **[2 marks]**

Answer / mark points: Corrected current = $0.24 - 0.04 = 0.20$ A. [1]
 $R = 4.0 / 0.20 = 20 \Omega$. [1] Using the uncorrected 0.24 A gives about 17 Ω , an underestimate.

1(d) Twenty repeated readings have a mean of 0.24 A. Has taking this mean removed the zero error? Explain. **[1 mark]**

Answer / mark points: No: the same +0.04 A offset affects every reading, so it remains in the mean. [1 for answer with reason] Repeats can reduce random variation, not remove this offset.



2 Which spring readings can be used

The trolley's spring buffer is compressed slowly using known forces. Compression is the decrease from its unloaded length. The same operator makes three measurements at each force using the same apparatus. Table 1 gives compression in mm.

Table 1

Force / N	Trial 1 / mm	Trial 2 / mm	Trial 3 / mm
0	0.0	0.0	0.0
1	4.8	5.0	5.2
2	9.8	10.0	10.2
3	14.8	15.0	15.2
4	19.8	29.8	20.2
5	24.8	25.0	25.2

2(a) Identify the independent variable and the dependent variable in the spring test. **[2 marks]**

Answer / mark points: Independent: applied force. [1] Dependent: compression of the spring. [1]
Not the spring's total length unless the required compression is then obtained.

2(b) Identify the reading that appears anomalous. Use the other repeats at the same force as evidence. **[2 marks]**

Answer / mark points: 29.8 mm at 4 N appears anomalous. [1]
The other two readings are 19.8 and 20.2 mm, close to 20 mm and about 10 mm below 29.8 mm. [1]
State values or an equivalent quantified comparison.

2(c) What should the operator do before deciding to exclude this reading from the mean? **[1 mark]**

Answer / mark points: Check the measurement/set-up and repeat the reading at the same force to investigate whether it arose from a measurement mistake. [1] Do not exclude a value simply because it is inconvenient.

2(d) A check confirms that the pointer slipped during the 29.8 mm reading. A replacement reading is 20.0 mm. Calculate the mean at 4 N using 19.8, 20.0 and 20.2 mm. **[1 mark]**

Answer / mark points: Mean = $(19.8 + 20.0 + 20.2) / 3 = 20.0$ mm. [1] The confirmed faulty reading is replaced, not included as a fourth repeat.

2(e) Calculate the mean compression at 1 N and at 5 N from Table 1. **[2 marks]**

Answer / mark points: At 1 N: $(4.8 + 5.0 + 5.2) / 3 = 5.0$ mm. [1]
At 5 N: $(24.8 + 25.0 + 25.2) / 3 = 25.0$ mm. [1]

2(f) The pointer vibrates after each load is changed. Suggest an improvement to the reading procedure and explain why it helps. **[2 marks]**

Answer / mark points: Wait for the pointer/spring to settle before reading. [1]
This avoids reading a changing position rather than the equilibrium compression, reducing variation in repeated measurements. [1] "Repeat more" alone does not address the stated cause.



3 Presenting the spring evidence

Use the checked means in Table 2, even if your earlier means differ. The spring remains within its limit of proportionality.

Table 2

Force / N	0	1	2	3	4	5
Mean compression / mm	0	5.0	10.0	15.0	20.0	25.0

3(a) Plot mean compression against force on Figure 1. Choose and label the axes with units, use suitable linear scales, plot all six points and draw a line of best fit. **[5 marks]**

Answer / mark points: Axes: force horizontal, mean compression vertical, both with units. [1]

Uniform scales using at least half the grid each way. [1]

Six correct points. [2; 1 for four or five] Tolerance: one tenth of a reference grid interval. Straight best fit through the trend and origin. [1] Reference intervals: 1 N and 5 mm.

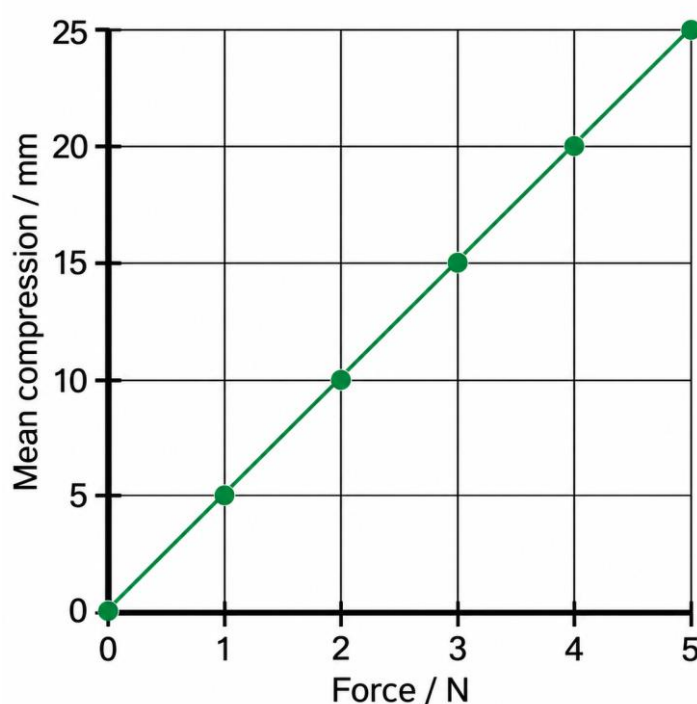


Figure 1

3(b) Use your best-fit line to determine the spring constant in N/m. Use $F = ke$; remember that compression e must be in metres. **[2 marks]**

Answer / mark points: From the line, $e = 25.0 \text{ mm} = 0.0250 \text{ m}$ at $F = 5.0 \text{ N}$. [1]

$k = F / e = 5.0 / 0.0250 = 200 \text{ N/m}$. [1] ECF from their line. This graph's gradient is 5.0 mm/N , not k .

3(c) Use your graph to estimate the compression at 2.5 N. **[1 mark]**

Answer / mark points: 12.5 mm. [1] Accept 12–13 mm or a consistent sensible reading from their best-fit line.

3(d) Does your graph support direct proportionality between compression and force over the tested range? Give graph evidence. **[2 marks]**

Answer / mark points: Yes: compression is directly proportional to force over this range. [1]

The best-fit line is straight and passes through the origin. [1] "They both increase" is insufficient evidence.

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4 Criticising the trainee graph

The same spring has an unloaded length of 50 mm. Its loaded lengths are 50, 45, 40, 35, 30 and 25 mm at forces of 0, 1, 2, 3, 4 and 5 N. Figure 2 shows these six data crosses and the trainee's attempted best-fit line. The scale numbers and crosses are correct; the draft contains errors. Use the data crosses, not the attempted line, for readings.

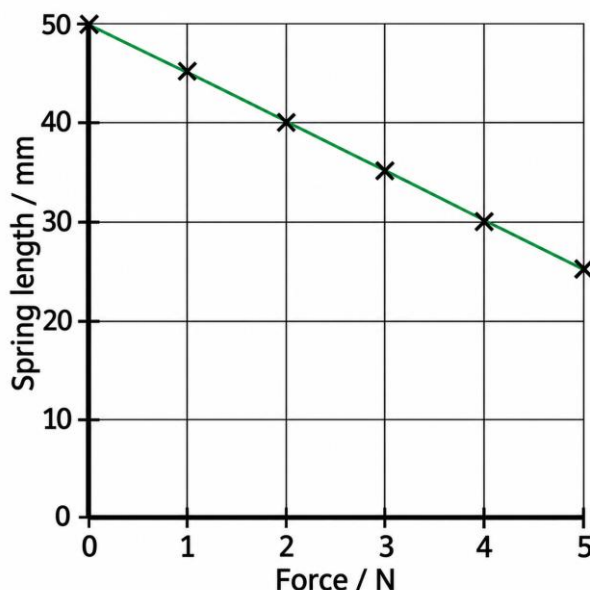


Figure 2

4(a) Identify the omission from the vertical-axis label in the trainee's graph. [1 mark]

Answer / mark points: The unit mm is missing; the label should be "Spring length / mm". [1] The teacher figure includes it.

4(b) Explain why the trainee's attempted best-fit line is unsuitable. Refer to the pattern of the data and to the no-force measurement. [2 marks]

Answer / mark points: The crosses show decreasing length, but the attempted line rises and misses five crosses. [1]

At zero force the length is 50 mm, not zero; forcing this line through the origin contradicts that measurement. [1] See the corrected descending teacher fit.

4(c) Read the spring length at 3 N from the data cross. Use the unloaded length of 50 mm to calculate the compression at this force. [2 marks]

Answer / mark points: Spring length = 35 mm. [1]

Compression = $50 - 35 = 15$ mm. [1] Length and compression are different quantities.

4(d) A constant +2 mm ruler offset changes the unloaded length from 50 mm to 52 mm and the loaded length from 45 mm to 47 mm. Calculate the recorded compression and explain whether this offset changes it. [2 marks]

Answer / mark points: Compression = $52 - 47 = 5$ mm. [1]

It is unchanged: the same +2 mm is present in both length readings and cancels when they are subtracted. [1] This cancellation does not apply to a single uncorrected length.

4(e) The operator reads the ruler from a different viewing angle each time. Explain how this can increase variation, and state how to reduce this effect. [2 marks]

Answer / mark points: Changing the viewing angle can make the pointer appear at different scale positions (parallax). [1]

Read with the eye level with the pointer and the line of sight perpendicular to the scale, using the same position each time. [1] A fixed wrong angle may instead produce a consistent bias.



5 Checking the chassis material

A solid, non-porous chassis sample is fully submerged without touching the cylinder scale. Its correctly measured mass is 54.0 g. The initial water volume is 30.0 cm³ and the final volume is 50.0 cm³. Use density = mass / volume; answers in g/cm³ are suitable here.

5(a) Calculate the sample's volume and density from the displacement measurements. **[2 marks]**

Answer / mark points: Volume = 50.0 – 30.0 = 20.0 cm³. [1]

Density = 54.0 / 20.0 = 2.70 g/cm³. [1]

5(b) In a repeat test, an air bubble sticks to the sample, giving a final volume of 52.0 cm³ instead of 50.0 cm³. The initial volume is still 30.0 cm³. Calculate the density estimate and explain the direction of its error. **[2 marks]**

Answer / mark points: Estimated density = 54.0 / (52.0 – 30.0) = 2.45 g/cm³ (3 s.f.). [1]

It is too low: the bubble makes the measured displaced volume too large for the same sample mass.

[1] Do not say the bubble increases the metal's true volume.

Table 3

Measurement set	Density estimates / g cm ⁻³
A before zero correction	3.09, 3.10, 3.11
A after zero correction	2.69, 2.70, 2.71
B with different equipment	2.68, 2.70, 2.72

5(c) Table 3 shows later density estimates. The accepted reference value is 2.70 g/cm³. Evaluate A's results before zero correction in terms of precision and accuracy. Use the data. **[2 marks]**

Answer / mark points: They are precise: the values cluster closely between 3.09 and 3.11 g/cm³.

[1]

They are not accurate relative to the reference: their mean is 3.10 g/cm³, consistently above 2.70

g/cm³. [1] A small spread does not demonstrate accuracy.

5(d) A check finds that A's empty balance shows a positive reading. State how A should correct this before weighing the sample, and explain why. **[2 marks]**

Answer / mark points: Zero/tare the empty balance before the sample is placed on it (or subtract the measured empty offset). [1]

This removes the positive zero offset from the measured mass, which would otherwise overestimate density for the same volume. [1] Taring with the sample already on the balance is not a valid sample-mass measurement.

5(e) After A corrects the balance, operator B repeats the test using different equipment. Compare their results in Table 3. Which aspect of measurement quality does this check? **[2 marks]**

Answer / mark points: The corrected A and B results agree closely, both centred on 2.70 g/cm³. [1]

This supports reproducibility because a different operator using different equipment obtains similar results. [1] Same operator and equipment would test repeatability.



6 Evaluating the heater evidence

The parcel-heater test uses a metal block of mass 0.50 kg. A joulemeter records 3000 J supplied electrically to the heater. The block's measured temperature rises from 20.0 °C to 26.0 °C. For this evaluation, the mass, energy and temperature instruments are correctly calibrated; the block loses thermal energy to the surroundings. Use $E = mc\Delta\theta$ to analyse the estimate made by assuming all electrical energy heats the block.

6(a) Calculate the temperature rise and the estimated specific heat capacity of the block. **[2 marks]**

Answer / mark points: $\Delta\theta = 26.0 - 20.0 = 6.0$ °C. [1]
 $c = E / (m\Delta\theta) = 3000 / (0.50 \times 6.0) = 1000$ J/(kg °C). [1]

6(b) Explain why using all 3000 J as the energy gained by the block overestimates its specific heat capacity. **[2 marks]**

Answer / mark points: Some electrical energy is transferred to the surroundings, so the block gains less than 3000 J. [1]

The calculation uses too large an energy numerator for the measured mass and temperature rise, giving too large a value of c . [1] Equivalent reasoning via a smaller temperature rise for the same electrical input is acceptable.

6(c) Two proposals are made: repeat the unchanged test ten times and average, or insulate the block and repeat under controlled conditions. Evaluate which better addresses the heat-loss bias. Explain the role of repeats and name one condition that should be matched for a fair comparison. **[4 marks]**

Answer / mark points: Prefer insulating the block: it reduces thermal energy transfer to the surroundings. [1]

More of the measured electrical input then heats the block, reducing the overestimate of c . [1]

Repeats and a mean can reduce random variation but do not remove the heat-loss bias in the unchanged method. [1]

Match a relevant condition, e.g. same block/mass, same initial block and room temperatures, same electrical input and heating duration, or same probe position. [1] Credit one valid condition. Do not credit changing the material while claiming a fair insulation comparison.

Review and improve

Require a named measurement, a stated limitation and a causal explanation. "More accurate" alone is not an evaluation. A non-zero intercept is not automatically an error. Timing is estimated, not trialled. No required-practical completion claim.

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