

AQA AS Measurement Errors, Accuracy and Precision solutions

Matching solutions and teaching prompts for the class review

Specification points covered

- 3.1.2(a) Identify random errors and systematic errors, including how they affect measurements.
- 3.1.2(b) Explain precision, repeatability, reproducibility, resolution and accuracy in measurement.

Teaching focus

Require complete working, correct SI units and precision justified by the data.
Use the common-error prompt to make pupils correct the method or language, not only the final number.

1. Measurement language

1. Define accuracy and precision in the context of a physical measurement. [2 marks]

Answer / mark points: Accuracy is closeness of a measured value to the true or accepted value. Precision is closeness of repeated measured values to one another.

Teacher prompt / common error: Accuracy refers to the true value; precision refers to the spread of repeats.

2. Distinguish repeatability from reproducibility. [2 marks]

Answer / mark points: Repeatability is agreement when the same method and equipment are used by the same person over a short interval. Reproducibility is agreement when the method, equipment, observer or location is changed.

Teacher prompt / common error: A repeated measurement is not automatically a reproducibility test unless a relevant condition changes.

3. Two infusion pumps are tested against a reference delivery of 5.00 mL. Pump A gives 5.33, 5.34, 5.33, 5.34 and 5.33 mL. Pump B gives 4.86, 5.07, 5.04, 5.10 and 4.93 mL. Compare the accuracy and precision of the two pumps. [4 marks]

Answer / mark points: Pump A has a very small spread, so it is precise, but its values are about 0.33 mL above the reference, so it is not accurate. Pump B has a larger spread, so it is less precise, but its mean is $(25.00/5) = 5.00$ mL, so it is accurate on average.

Teacher prompt / common error: Insist on both the spread and the reference value. A tight cluster can still be inaccurate.



2. Error patterns and instrument limits

4. For each pump in Question 3, identify the dominant type of measurement error and state one suitable action to improve the result. [3 marks]

Answer / mark points: Pump A suggests a systematic calibration or zero error; calibrate it against the reference or correct the offset. Pump B shows random variation; take more repeats and use the mean. Credit a clearly linked error and improvement.

Teacher prompt / common error: Repeats do not remove a calibration offset; calibration does not remove unpredictable scatter.

5. A digital flow sensor changes its display in steps of 0.01 mL s^{-1} . An analogue meter has scale divisions of 0.1 mL s^{-1} . State the resolution of each instrument and explain which can detect the smaller change. [2 marks]

Answer / mark points: Digital resolution = 0.01 mL s^{-1} . Analogue resolution = 0.1 mL s^{-1} . The digital sensor detects the smaller change because its resolution value is smaller.

Teacher prompt / common error: A smaller numerical resolution means the instrument can distinguish smaller changes.

6. A balance reads $+0.07 \text{ g}$ when empty. It displays 12.64 g for a component. Determine the corrected mass and explain why repeating the uncorrected reading would not remove this error. [2 marks]

Answer / mark points: Corrected mass = $12.64 - 0.07 = 12.57 \text{ g}$. The zero error is systematic, so repeated readings remain shifted in the same direction.

Teacher prompt / common error: Positive zero error is subtracted. Repetition cannot remove a systematic shift.

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3. Correcting and comparing measurements

7. A micrometer has a zero reading of -0.006 mm. Four displayed diameter readings are 0.842, 0.839, 0.841 and 0.840 mm. Calculate the corrected mean diameter and explain why readings are taken at several positions. [4 marks]

Answer / mark points: Mean displayed diameter = $(0.842 + 0.839 + 0.841 + 0.840)/4 = 0.8405$ mm. Corrected mean = $0.8405 - (-0.006) = 0.8465$ mm, reported as 0.847 mm. Several positions reveal variation in diameter and reduce the influence of local irregularity when a mean is used.

Teacher prompt / common error: A negative zero reading is subtracted, so the correction increases the result.

8. A glacier-temperature sensor gives closely grouped readings during one visit. A second team using different equipment obtains a mean 0.36 °C higher under the same conditions. Explain what this shows about repeatability and reproducibility. [3 marks]

Answer / mark points: The close grouping for one team supports good repeatability. The difference between teams shows poor reproducibility. A calibration difference, method difference or environmental control should be investigated.

Teacher prompt / common error: Repeatability and reproducibility describe agreement under different testing conditions.

9. A pupil times one rotation of a wind-tunnel fan with a stopwatch. Explain two changes that would improve the quality of the period measurement and identify the error each change addresses. [4 marks]

Answer / mark points: Time many rotations and divide by their number: the fixed reaction-time error becomes a smaller fraction of the total time. Repeat the timing and take a mean to reduce random variation. A light gate can remove human reaction time and provide finer resolution; credit two changes with correct links.

Teacher prompt / common error: The explanation must connect each change to reaction-time, resolution or random scatter.

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4. Selecting and judging instruments

10. Choose a suitable instrument for each task and justify the choice using resolution: (a) diameter of a 0.62 mm wire; (b) length of a 1.20 m air track; (c) delivery of 25.0 cm³ of liquid. [3 marks]

Answer / mark points: (a) Micrometer screw gauge, typically 0.01 mm resolution. (b) Metre rule or tape with millimetre divisions and sufficient range. (c) 25.0 cm³ volumetric pipette, which is more appropriate than a coarse measuring cylinder for a fixed accurate volume.

Teacher prompt / common error: Match both range and resolution to the task; an instrument can be precise but impractical for the required range.

11. A digital balance gives 8.420, 8.420 and 8.421 kg for a certified 8.000 kg mass. Describe the data using the terms precise, repeatable and accurate. [3 marks]

Answer / mark points: The values are closely grouped, so they are precise and repeatable. They are not accurate because they are about 0.420 kg above the certified value. The pattern suggests a systematic calibration error.

Teacher prompt / common error: Do not call the readings accurate because they contain many decimal places.

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5. Extended application

12. A testing laboratory must compare infusion pumps used at three hospitals. Design a quality-assurance method that can reveal random and systematic errors and test precision, repeatability and reproducibility. Include the reference measurement, repeats, instrument checks and how the results will be compared. [6 marks]

Answer / mark points: Use a traceable reference volume or determine delivered mass with a calibrated balance and known liquid density. Check zero and calibration before testing; control liquid, temperature, programmed volume and delivery time. Take several readings for each pump and calculate a mean and spread to assess precision and random error. Repeat with the same operator and apparatus for repeatability. Have different operators or hospitals repeat with independently checked equipment for reproducibility. Compare every mean with the reference to reveal systematic offset, compare spreads to reveal random error, and record instrument resolution. Investigate or correct any consistent offset before judging the pumps.

Teacher prompt / common error: A high-level response links each procedure to a named aspect of measurement quality and includes a reference value.

Language and method check

Award marks for independent, creditworthy physics steps rather than the amount of working shown.

Where an equivalent method is valid, accept it only when the reasoning, units and final precision remain consistent.

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