3.1 Measurements and their Errors: 30-minute Pack

AQA 7408 · Calculator allowed · about 30 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Significant figures indicate the precision of a measured or calculated quantity.

(a) A student measures the diameter of a wire as 0.42 mm using a micrometer of resolution 0.01 mm. State the number of significant figures in this measurement. **(1)**

(b) Calculate the cross-sectional area of the wire in part (a), using $A = \pi \times d^2 / 4$, giving your answer in m^2 to an appropriate number of significant figures. **(3)**

(c) A calculation gives a result of 12.3456 N. Round this value to 3 significant figures. **(1)**

(d) Explain why it is not appropriate to quote the final answer to a calculation to more significant figures than the least precise measurement used in that calculation. **(2)**

(Total for Question 1 is 7 marks)

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2 Precision, accuracy and resolution describe different aspects of the quality of a measurement.

(a) Define the term 'resolution' of a measuring instrument. **(1)**

(b) Define the term 'accuracy' of a measurement. **(1)**

(c) Two students each measure the length of the same object several times. Student A's repeated readings are tightly clustered together but consistently 3 mm below the true length. Student B's readings are centred on the true length but are widely spread out. Describe what this tells you about the precision and accuracy of each student's set of results. **(2)**

(d) A metre ruler has a resolution of 1 mm. State the absolute uncertainty in a single length measurement made with this ruler. **(1)**

(Total for Question 2 is 5 marks)

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3 Significant figures indicate how precisely a value is known; recognising them correctly, and rounding calculated results appropriately, is an essential exam skill.

(a) State the number of significant figures in the measurement 0.070060 m. **(1)**

(b) A calculation gives a result of 143.7568 N, using two measured quantities that were each quoted to 3 significant figures. State this result to an appropriate number of significant figures. **(1)**

(c) A student measures a potential difference V = 6.0 V (2 significant figures) across a resistor and a current I = 0.24 A (2 significant figures) through it. Calculate the resistance R = V / I, giving your answer to an appropriate number of significant figures. **(2)**

(d) Explain the difference between the number of decimal places and the number of significant figures in a measured value, using 0.070060 m as your example. **(2)**

(Total for Question 3 is 6 marks)

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4 Measurements are always subject to systematic and/or random error.

(a) A top-pan balance is not zeroed before use and reads 0.05 g with nothing on the pan. Every subsequent mass measured with this balance is too high by the same 0.05 g. Identify the type of error this illustrates, and state how the student should correct the affected readings. **(2)**

(b) A student reads the position of a pointer on an analogue ammeter scale from an angle, rather than looking directly along the pointer from directly above the scale. Name the type of error this introduces, and state one way to reduce it. **(2)**

(c) The student re-zeros the balance from part (a) correctly, then measures the same mass 6 times, obtaining slightly different readings each time because of air currents disturbing the balance. Explain whether this variation is a systematic or a random error, and describe how the student could reduce its effect on the reported mean value. **(3)**

(Total for Question 4 is 7 marks)

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Mark scheme · 3.1 Measurements and their Errors: 30-minute Pack

Question 1

(a) 2 (significant figures) cao **B1**

(a) Answer: 2 significant figures

(b) converts diameter to metres: d = 4.2 x 10^{-4} m **M1**

(b) correct substitution and evaluation: A = π x (4.2 x 10^{-4})^2 / 4 = 1.385 x 10^{-7} m^2 **M1**

(b) 1.4 x 10^{-7} m^2 (awrt, to 2 s.f., matching the 2 s.f. of the diameter) **A1**

(b) Answer: A = 1.4 x 10^{-7} m^2

(c) 12.3 N (cao) **B1**

(c) Answer: 12.3 N

(d) the overall result cannot be known more precisely/certainly than its least precise input measurement oe **B1**

(d) quoting extra significant figures would imply a false level of precision/accuracy that the data does not support **B1**

(d) Answer: A calculated result is only as precise as the least precise value used to find it; extra significant figures would falsely suggest greater precision than the measurements justify.

Question 2

(a) the smallest change in the quantity being measured that causes a detectable/observable change in the instrument's reading oe **B1**

(a) Answer: The smallest change in a quantity that an instrument can detect.

(b) how close a measured value is to the true (accepted) value of the quantity oe **B1**

(b) Answer: How close a measurement is to the true value of the quantity being measured.

(c) Student A: precise (small spread/good repeatability) but not accurate, because of a systematic error offsetting all readings from the true value **B1**

(c) Student B: accurate (mean value close to/matches the true value) but not precise, because of a large random error causing a wide spread of readings **B1**

(c) Answer: Student A is precise but not accurate (small spread, offset from true value by a systematic error). Student B is accurate but not precise (correct mean, but a large random spread).

(d) ± 0.5 mm (half the smallest scale division) oe **B1**

(d) Answer: ± 0.5 mm

Question 3

(a) 5 (significant figures) cao **B1**

(a) Answer: 5 significant figures

(b) 144 N (cao) **B1**

(b) Answer: 144 N

(c) R = 6.0 / 0.24 = 25.0 ohm **M1**

(c) 25 ohm, quoted to 2 s.f. to match the precision of the input data (cao) **A1**

(c) Answer: 25 ohm (2 s.f.)

(d) 0.070060 m has 6 decimal places (digits after the decimal point) but only 5 significant figures, because the leading zeros are not significant **B1**

(d) decimal places depend on how the number is written/the unit used, whereas significant figures reflect the actual precision of the measurement regardless of the unit oe **B1**

(d) Answer: 0.070060 m has 6 decimal places but only 5 significant figures; decimal places depend on how the value is written (and its unit), while significant figures reflect the true precision of the measurement.

Question 4

(a) systematic (zero) error **B1**

(a) subtract 0.05 g from every reading taken with the uncorrected balance (or re-zero the balance before use) oe **B1**

(a) Answer: This is a systematic (zero) error; the student should subtract 0.05 g from every reading taken (or zero the balance before use).

(b) parallax error **B1**

(b) view the scale directly from above/in line with the pointer (e.g. using a mirror behind the scale to check the pointer and its reflection align) oe **B1**

(b) Answer: This is a parallax error; it can be reduced by viewing the scale directly from above the pointer, for example using a mirror scale to check the pointer and its reflection coincide.

(c) random error, because the readings vary unpredictably above and below the true value rather than being consistently offset in one direction **B1**

(c) the air currents cause small, unpredictable fluctuations in each individual reading **B1**

(c) repeating the measurement many times and calculating the mean reduces the effect of this random variation on the reported value oe **B1**

(c) Answer: This is a random error, since the air currents cause the readings to scatter unpredictably above and below the true value rather than shifting them consistently in one direction; taking many repeat readings and calculating the mean reduces its effect on the reported mass.

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