3.9 A-Level Physics: Required Practicals and Uncertainties: Test Pack

AQA 7408 · Calculator allowed · about 25 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question tests general ideas about measurement uncertainty used throughout the required practicals.

(a) Which of the following is an example of a systematic error? **(1)**

- ☐ A) A student's reaction time varies each time they start a stopwatch.
- ☐ B) A top-pan balance is not zeroed correctly, so every reading is 0.05 g too high.
- ☐ C) The count rate from a radioactive source fluctuates randomly from one 10 s interval to the next.
- ☐ D) Mains-voltage fluctuations cause small variations in a digital meter's readings.

(b) State the difference between the resolution of a measuring instrument and the accuracy of a measurement. **(2)**

(c) A student uses a metre ruler (resolution 1 mm) to measure the extension of a spring, obtaining a single reading of 12.0 mm. Taking the absolute uncertainty as half the resolution, calculate the percentage uncertainty in this reading. **(2)**

(d) The student instead measures the total extension of 10 identical springs connected in series, obtaining 118 mm, then divides by 10 to find the extension of one spring. Explain why this method reduces the percentage uncertainty in the extension of one spring. **(2)**

(Total for Question 1 is 7 marks)

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2 A student investigates radioactive decay using a sealed protactinium generator and a GM tube connected to a counter. The background count rate (measured with no source present) is 20 counts per minute (cpm). Measured (raw) and corrected (background-subtracted) count rates are:

t (s): 0, 30, 60, 90, 120, 150, 180

Measured count rate (cpm): 320, 232, 170, 126, 95, 73, 58

Corrected count rate (cpm): 300, 212, 150, 106, 75, 53, 38

(a) Explain why the background count rate must be measured separately and subtracted from each reading before the decay is analysed. **(2)**

(b) Show that the corrected count rate at t = 90 s is 106 cpm. **(2)**

(c) The student plots ln(corrected count rate) against t and obtains a straight line of best fit with gradient -0.01155 s^{-1}. Use this to determine the decay constant and the half-life of the sample. **(3)**

(d) Suggest two advantages of finding the half-life from the gradient of a ln(count rate)-time graph, rather than reading a single half-life directly off a raw count rate-time graph. **(2)**

(Total for Question 2 is 9 marks)

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Mark scheme · 3.9 A-Level Physics: Required Practicals and Uncertainties: Test Pack

Question 1

(a) B cao **B1**

(a) Answer: B

(b) resolution is the smallest change in a quantity that gives a perceptible/detectable change in an instrument's reading (the smallest scale division it can distinguish) oe **B1**

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

(b) Answer: Resolution = smallest detectable change in a reading; accuracy = how close a reading is to the true value.

(c) absolute uncertainty = 0.5 mm; (0.5/12.0) x 100 (correct substitution) **M1**

(c) 4.2% (awrt 4.2) cao **A1**

(c) Answer: 4.2%

(d) the absolute uncertainty in reading the ruler is still about 0.5 mm (fixed by the ruler's resolution), but this is now spread over a ten times larger measured length oe **B1**

(d) so the percentage uncertainty in the total (0.5/118 x 100 = 0.42%) is about ten times smaller than for a single spring (4.2%), and dividing by 10 to get one spring's extension does not change this percentage oe **B1**

(d) Answer: The fixed 0.5 mm reading uncertainty is spread over a ten times longer length, so the percentage uncertainty falls from about 4.2% to about 0.4%.

Question 2

(a) background radiation (e.g. from cosmic rays, rocks/building materials, other radioactive sources nearby) is detected by the GM tube even with no sample present oe **B1**

(a) this background is unrelated to the decay of the sample, so it must be subtracted to avoid a systematic error/bias in the corrected count rate used to find the decay constant oe **B1**

(a) Answer: Background radiation is always present and unrelated to the source's decay, so it must be subtracted to avoid a systematic error.

(b) 126 - 20 (correct method: measured minus background) **M1**

(b) 106 cpm cso (answer given) **A1**

(b) Answer: 106 cpm

(c) decay constant, λ = magnitude of gradient = 0.01155 s^{-1} (since ln C = ln C0 - λ t, gradient = -λ) **M1**

(c) half-life T(1/2) = ln(2) / λ (correct rearrangement) **M1**

(c) T(1/2) = 60.0 s (= 1.00 minute) (awrt 60.0) cao **A1**

(c) Answer: λ = 0.01155 s^{-1}; half-life = 60.0 s (1.00 minute)

(d) the gradient method uses every data point (via a line of best fit), averaging out the random fluctuations inherent in radioactive decay, rather than relying on one possibly anomalous reading oe **B1**

(d) taking logarithms converts the exponential decay curve into a straight line, making it much easier to identify anomalous points and to determine the constant (decay rate) precisely from the gradient oe **B1**

(d) Answer: Using the gradient of a straight-line log graph averages out random count-rate fluctuations across all readings and makes anomalies easier to spot, rather than relying on a single reading from a curve.

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