

AQA AS Uncertainties, Error Bars and Estimation solutions

Matching solutions and teaching prompts for the class review

Specification points covered

- 3.1.2(c) Use absolute, fractional and percentage uncertainties to represent uncertainty in a final answer.
- 3.1.2(d) Combine uncertainties for quantities found by addition, subtraction, multiplication, division or powers.
- 3.1.2(e) Represent uncertainty in a graph data point using error bars.
- 3.1.2(f) Determine uncertainty in the gradient and intercept of a straight-line graph using best and worst acceptable lines.
- 3.1.2(g) Link the significant figures in a measured value to its associated uncertainty.
- 3.1.3(a-b) Make order-of-magnitude estimates and use physics knowledge to make derived estimates.

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. Reporting uncertainty

1. A length is recorded as (12.4 ± 0.2) cm. State its absolute uncertainty and calculate its fractional and percentage uncertainties. [3 marks]

Answer / mark points: Absolute uncertainty = 0.2 cm. Fractional uncertainty = $0.2/12.4 = 0.0161$. Percentage uncertainty = 1.61%, normally quoted as about 1.6%.

Teacher prompt / common error: Fractional uncertainty has no unit; percentage uncertainty is the fraction multiplied by 100.

2. A voltmeter result is initially written as (8.347 ± 0.19) V. Rewrite the result using suitable decimal places and explain your choice. [2 marks]

Answer / mark points: A suitable form is (8.35 ± 0.19) V. The measured value and its uncertainty should be quoted to the same decimal place; retaining 8.347 implies unsupported precision.

Teacher prompt / common error: The value and uncertainty must end at the same decimal place.

3. A meteorite fragment displaces water from (54.0 ± 0.5) cm³ to (71.0 ± 0.5) cm³. Calculate its volume and absolute uncertainty. [2 marks]

Answer / mark points: $V = 71.0 - 54.0 = 17.0$ cm³. For subtraction, absolute uncertainties add: $\Delta V = 0.5 + 0.5 = 1.0$ cm³. Therefore $V = (17.0 \pm 1.0)$ cm³.

Teacher prompt / common error: For a difference, add the absolute uncertainties of the two readings.



2. Combining uncertainties

4. The fragment in Question 3 has mass (146.2 ± 0.1) g. Calculate its density, the percentage uncertainty in the density and a suitable absolute uncertainty for the density. [4 marks]

Answer / mark points: $\rho = m/V = 146.2/17.0 = 8.60 \text{ g cm}^{-3}$. Percentage uncertainty = $(0.1/146.2 \times 100) + (1.0/17.0 \times 100) = 0.068\% + 5.88\% = 5.95\%$, about 6.0%. Absolute uncertainty = $0.0595 \times 8.60 = 0.51 \text{ g cm}^{-3}$, so a suitable result is $(8.6 \pm 0.5) \text{ g cm}^{-3}$.

Teacher prompt / common error: For division, add fractional or percentage uncertainties. Do not add the absolute uncertainties in grams and cubic centimetres.

5. A spherical sensor has diameter (24.0 ± 0.2) mm. Its volume is proportional to d^3 . Calculate the percentage uncertainty in its volume. [2 marks]

Answer / mark points: Percentage uncertainty in $d = 0.2/24.0 \times 100 = 0.833\%$. For V proportional to d^3 , percentage uncertainty in $V = 3 \times 0.833\% = 2.50\%$.

Teacher prompt / common error: The power multiplies the percentage uncertainty; it does not cube it.

6. A thermal store receives (142 ± 4) J and delivers (85 ± 3) J. Calculate the energy lost and its absolute uncertainty. [2 marks]

Answer / mark points: Energy lost = $142 - 85 = 57 \text{ J}$. Absolute uncertainties add for subtraction: $\Delta E = 4 + 3 = 7 \text{ J}$. Result: $(57 \pm 7) \text{ J}$.

Teacher prompt / common error: The measured quantities are subtracted, but their absolute uncertainties are added.

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3. Products, quotients and error bars

7. A component has potential difference (5.00 ± 0.05) V and current (0.240 ± 0.006) A. Calculate its resistance and the percentage and absolute uncertainties in the resistance. [3 marks]

Answer / mark points: $R = V/I = 5.00/0.240 = 20.8 \, \Omega$. Percentage uncertainty = $0.05/5.00 \times 100 + 0.006/0.240 \times 100 = 1.0\% + 2.5\% = 3.5\%$. Absolute uncertainty = $0.035 \times 20.8 = 0.73 \, \Omega$, so $R = (20.8 \pm 0.7) \, \Omega$.

Teacher prompt / common error: Add percentage uncertainties for a quotient, then convert back to an absolute uncertainty only at the end.

8. A graph point has coordinates $x = 4.0 \pm 0.2$ and $y = 12.0 \pm 0.8$. State the two endpoints of its horizontal error bar and the two endpoints of its vertical error bar. [2 marks]

Answer / mark points: Horizontal error bar endpoints: $x = 3.8$ and 4.2 at $y = 12.0$. Vertical error bar endpoints: $y = 11.2$ and 12.8 at $x = 4.0$.

Teacher prompt / common error: Each error bar extends one stated uncertainty on either side of the plotted point.

9. For a solar-panel graph, the maximum acceptable line passes through (1.0, 2.0) and (6.0, 17.5). The minimum acceptable line passes through (1.0, 3.0) and (6.0, 16.0). Calculate $G_{\max}$, $G_{\min}$, the best estimate of the gradient, its absolute uncertainty and its percentage uncertainty. [5 marks]

Answer / mark points: $G_{\max} = (17.5 - 2.0)/(6.0 - 1.0) = 3.10$. $G_{\min} = (16.0 - 3.0)/5.0 = 2.60$. Best estimate = $(3.10 + 2.60)/2 = 2.85$. Absolute uncertainty = $(3.10 - 2.60)/2 = 0.25$. Percentage uncertainty = $0.25/2.85 \times 100 = 8.8\%$.

Teacher prompt / common error: Use a large triangle for each acceptable gradient. The uncertainty is half the max-min range.

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4. Gradient, intercept and presentation

10. The acceptable intercepts from the graph are -0.6 and $+0.2$. Calculate the best estimate of the intercept and its absolute uncertainty. [2 marks]

Answer / mark points: Best intercept = $[-0.6 + (+0.2)]/2 = -0.2$. Absolute uncertainty = $[0.2 - (-0.6)]/2 = 0.4$. Result: -0.2 ± 0.4 .

Teacher prompt / common error: The best estimate is the midpoint of the limiting values, even when the interval crosses zero.

11. A measured distance is reported as (2.483 ± 0.071) m. Give a more appropriate presentation of the value and uncertainty, and state the rule you used. [2 marks]

Answer / mark points: A suitable presentation is (2.48 ± 0.07) m. Quote the uncertainty to a sensible number of significant figures and quote the measured value to the same decimal place.

Teacher prompt / common error: Extra decimal places are not evidence of reduced uncertainty.

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5. Estimation in an unfamiliar context

12. A Mars habitat contains 75 m^3 of air of density 1.2 kg m^{-3} . Take the mean mass of one air molecule as $4.8 \times 10^{-26} \text{ kg}$. Estimate the order of magnitude of the number of molecules in the habitat. [3 marks]

Answer / mark points: Air mass $\approx \rho V = 1.2 \times 75 = 90 \text{ kg}$. Number of molecules $\approx 90 / (4.8 \times 10^{-26}) = 1.9 \times 10^{27}$. Nearest order of magnitude: 10^{27} molecules.

Teacher prompt / common error: An order-of-magnitude estimate should show the physical model before rounding to a power of ten.

13. A 12 m^2 solar array receives an average intensity of 600 W m^{-2} for 7.0 h and is 20% efficient. Estimate the electrical energy produced and give its nearest order of magnitude. Assess a claim that it produces $5 \times 10^9 \text{ J}$ each day. [4 marks]

Answer / mark points: Power output $\approx I A \eta = 600 \times 12 \times 0.20 = 1440 \text{ W}$. Time $= 7.0 \times 3600 = 2.52 \times 10^4 \text{ s}$. Energy $\approx 1440 \times 2.52 \times 10^4 = 3.63 \times 10^7 \text{ J}$. The nearest order of magnitude is 10^8 J . The claim $5 \times 10^9 \text{ J}$ is about 140 times too large and is not supported.

Teacher prompt / common error: Convert hours to seconds and apply efficiency. Compare the claim by a factor, not by vague language.

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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