InkPhysics

ANSWER BOOK

Estimation and orders of magnitude

Measurements · Year 12

AQA 3.1.3 · CIE 1.1.2 · OCR A 2.1.1(b)

18 questions · 54 marks

NAVY EDITION

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SECTION A · Warm-up

A1 The order of magnitude is the size of a quantity to the nearest power of ten (1), obtained by rounding it to the closest value of 10^n (1). [2]

A2 (a) About 0.1 kg, so 10^{-1} kg (1). (b) About 30 m s^{-1}, so 10^{1} m s^{-1} (1). [2]

A3 (a) 10^{7}: orders of magnitude compare by ratio, and 4.5 is nearer 10 than 1 (the crossover is $\sqrt{10} \approx 3.2$) (1). (b) 10^{-4} (1). [2]

A4 (a) About 10^{-10} m (1). (b) A door is about 2 m tall, so 10^{0} m (2 is below the crossover of $\sqrt{10} \approx 3.2$) (1). [2]

A5 A car has a mass of order 10^3 kg (roughly a tonne, about the mass of fifteen adults) (1). The calculated value is about a thousand times too large, three orders of magnitude, so an error such as a slipped power of ten or a unit mix-up must have occurred (1). [2]

SECTION B · Standard

B1 Beats $\approx 70 \times 60 \times 24 \times 365 \times 80$ (1) $\approx 2.9 \times 10^9$ (1), which is of order 10^9 beats (1). [3]

B2 1 m = 100 cm (1), so the number = 100^3 (1) = 1×10^6 cubes, of order 10^6 (1). [3]

B3 KE = $\tfrac{1}{2}mv^2$ (1) $\approx \tfrac{1}{2} \times 70 \times 5^2$ (1) ≈ 875 J (1), which is of order 10^3 J (1). [4]

B4 Ratio $\approx (6 \times 10^{24})/60$ (1) = 1×10^{23} (1), so of order 10^{23} (1). [3]

B5 Sensible room dimensions, e.g. 10 m × 8 m × 3 m, give a volume of about 240 m^3 (1). Mass = $\rho V \approx 1.2 \times 240 \approx 288$ kg (1), which is of order 10^2 kg (1). [3]

B6 Volume ≈ 0.002 $m^3 \times 365 \times 80$ (1) ≈ 58 m^3 (1). 58 is above the crossover of $\sqrt{10} \times 10 \approx 32$, so the order of magnitude is 10^2 m^3 (1). [3]

B7 Take the walker's mass as about 70 kg (1). $E = mgh \approx 70 \times 10 \times 1000 = 7 \times 10^5$ J (1). 7 is above the crossover $\sqrt{10} \approx 3.2$, so this rounds up to order 10^6 J (1). [3]

SECTION C · Stretch

C1 Breaths ≈ 15 × 60 × 24 = 21600 ≈ 2×10^4 a day (1), of order 10^4 (1). Over 80 years: $2 \times 10^4 \times 365 \times 80$ (1) ≈ 6×10^8, of order 10^9 breaths (1). [4]

C2 $Q = mc\Delta\theta$ (1) ≈ 0.25 × 4200 × 80 (1) ≈ 84000 J (1), which is of order 10^5 J (1). [4]

C3 They give a quick check on whether a detailed answer is reasonable, catching errors of many powers of ten (1). They also let you judge whether something is feasible (1), or compare the sizes of quantities, without needing precise data or a full calculation (1). [3]

C4 Sensible benchmarks: mass of a tennis ball ≈ 0.06 kg, serve speed ≈ 50 m s^{-1} (1). $KE = \frac{1}{2}mv^2 \approx \frac{1}{2} \times 0.06 \times 50^2 \approx 75$ J, of order 10^2 J (1). The student's value is about 1000 times larger, three orders of magnitude, so it is not reasonable (1). A factor of 1000 in energy suggests the mass was left in grams instead of kilograms (1). [4]

C5 Volume of grain ≈ $(0.5 \times 10^{-3})^3 \approx 1.25 \times 10^{-10}$ m^3 (1). Volume of an atom ≈ $(10^{-10})^3 = 10^{-30}$ m^3 (1). Number ≈ $1.25 \times 10^{-10}/10^{-30} \approx 1.25 \times 10^{20}$ (1), so of order 10^{20} atoms (1). [4]

C6 Distance = 150 000 km = 1.5×10^8 m (1). Turns = distance/circumference ≈ $1.5 \times 10^8/2 \approx 7.5 \times 10^7$ (1), which is of order 10^8 turns (1). [3]