Question 2 (Answer: **D**)

- $X = 4\pi^2 L/T^2 = 4\pi^2(6.8)/2.42^2 = 45.8$ cm s^{-2}.
- T is squared, so $\Delta X/X = \Delta L/L + 2\Delta T/T = 1.5\% + 6.6\% = 8.1\%$, giving $\Delta X \approx 4$ cm s^{-2}.
- C forgets to double the time's share; the value is then rounded to match, so 46 ± 4.

Question 2 (Answer: **D**)

- Precision is about how closely repeated readings agree with each other.
- B is the definition of accuracy – closeness to the accepted value.
- A and C describe the instrument's resolution, which permits precision but does not demonstrate it.

Question 4 (Answer: **C**)

- From $s = \frac{1}{2}gt^2$, the acceleration is $g = 2s/t^2$.
- The time is squared, so its percentage uncertainty is doubled: $2 \times 4\% = 8\%$.
- The distance contributes nothing here, so B – forgetting to double – is the trap.

Question 2 (Answer: **B**)

- The readings lie 3 to 4 mm below the true 895 mm, so they are not accurate to within 1 mm.
- They span only 891 to 892 mm, so they do agree with each other to within 1 mm.
- Precise but not accurate is the signature of a systematic error, such as a zero error.

Question 3 (Answer: **B**)

- With $s = \frac{1}{2}gt^2$ the acceleration is $g = 2s/t^2$, so the shares combine as $\%s + 2 \times \%t$.
- $0.6\% + 2 \times 0.05\% = 0.7\%$.
- The time is measured very precisely here, so the distance dominates the total.

2(a)(i)	Final value of *d* in the range 4.0 cm to 8.0 cm with unit.
2(a)(ii)	Absolute uncertainty in *d* in range 0.2 cm to 0.6 cm Correct method of calculation to find percentage uncertainty e.g. absolute uncertainty / value from **2(a)(i)**) × 100. If repeated readings have been taken, then the uncertainty can be half the range if the working is clearly shown, but NOT zero if values are equal.
2(b)	Value of *L* in the range 85.0 cm to 100.0 cm with unit (somewhere)

2(c)(i)	**Raw** values of *h* to the nearest millimetre with unit (seen somewhere)
	Value of final *t* in the range 1.0 s to 5.0 s with unit
	Evidence of repeated measurements of *t*
2(c)(ii)	Value of *a* calculated correctly
2(c)(iii)	Justification for significant figures in *a* linked to significant figures in *L* and *t*.
2(d)	Second values of *h* **and** *t*.
	Second value of *t* **greater** than first value of *t*
2(e)	Two values of *k* calculated correctly. The final *k* values must not be written as fractions or given to only one significant figure.
2(f)	Calculation of percentage difference between candidate's two *k* values **and** comparison of percentage difference with 15%, leading to a consistent conclusion.

2(g)(i)	**1 mark for each point up to a maximum of 4.** A Two readings are <u>not enough to draw a conclusion</u> **or** not enough *k* values to draw a conclusion B Difficulty with measuring <u>*d* or *diameter*</u> with reason e.g. parallax / <u>base</u> / <u>bottom</u> of the bottle is not uniform / edges of the <u>base</u> / <u>bottom</u> of the bottle is curved C Difficult to set / measure the value of <u>*L* / length</u> with a reason e.g. difficult to place the bottle in the exact same place each time / cannot judge the centre line of the bottle / parallax error D Difficult to measure <u>*h*</u> or <u>height</u> with a reason e.g. bottle distorts view of water / refraction effects / parallax error / non-uniform shape (of bottle) E Difficulty with the bottle rolling / moving down the rulers (in a straight line) with a reason e.g. rulers bend / ruler(s) move (when bottle is rolling) / rulers are not parallel / bottle is not uniform (shape) / wooden strip is not parallel to the bench / rulers are not at the same height F Difficult to measure <u>*t* / time</u> with a reason e.g. knowing or judging when bottle reaches the end of rulers
2(g)(ii)	**1 mark for each point up to a maximum of 4.** A Take more readings (for different values of ***h***) <u>and</u> plot a graph **or** take more readings <u>and</u> compare *k* values B Use caliper C Method to hold the bottle at the start / top of rulers e.g. (card) stop D Use a straight-sided / uniform (diameter) bottle E Use a (single) plank / ramp **or** method of fixing rulers (to wooden strip or bench) e.g. adhesive putty, tape G Improved timing method e.g. video (record / film) <u>and</u> with a timer in view / use frame-by-frame

Question 2 (Answer: **D**)

- Precision is the spread of the repeats; accuracy is closeness to the true 9.81 m s^{-2}.
- D's three values differ by only 0.1 m s^{-2}, so they are precise – but they cluster around 10.1.
- C is just as tightly grouped, but it sits on the true value, so it is precise and accurate.

Question 3 (Answer: **B**)

- $V = \frac{\pi}{6}d^3 = \frac{\pi}{6}(5.26)^3 = 76.2\ \text{cm}^3$.
- A cube triples the fractional uncertainty: $3 \times 0.02/5.26 = 1.14\%$.
- $\Delta V = 0.0114 \times 76.2 = 0.87\ \text{cm}^3$; A comes from not tripling.

Question 3 (Answer: **B**)

- $\rho = m/L^3 = 975/5.0^3 = 7.8\ \text{g cm}^{-3}$, so every option has the right value.
- The mass contributes $10/975 = 1.0\%$; the side is cubed, so it contributes $3 \times 1/50 = 6\%$.
- Adding gives 7.0% – the cube is the trap, since a length used three times counts three times.

Question 12 (Answer: **D**)

- The volume is $\pi(d/2)^2 h$, so its uncertainty is $2 \times 3\% + 2\% = 8\%$.
- Density is mass over volume, so the percentages add: $10\% + 8\% = 18\%$.
- C gives 15% by forgetting to double the diameter's share for the squared radius.

1(a)	how close the (measured) value is to the true value (of the quantity)
1(b)(i)	(ρ =) m / V
	= $31.3 \times 10^{-3} / (1.53 \times 10^{-2})^3 = 8.7 \times 10^3$ (kg m^{-3})
1(b)(ii)	(0.5 / 31.3) or (0.01 / 1.53) % uncertainty = (0.016 × 100) + 3 × (0.0065 × 100)
	= 4%
1(b)(iii)	The ranges (of the densities of A and B) overlap **or** the (calculated) density of A is within the range of the density of B **or** the difference in densities is within the uncertainty (of B)
	(so) they could be the same