Question number	Answer		Mark
4(a)	The uncertainty is the same for both methods **Or** The resolution of the metre rule is 1mm	(1)	
	Student B's measurement will be larger therefore the percentage uncertainty will be smaller	(1)	
	Or		
	Calculation of percentage uncertainty for both methods using same uncertainty shown	(1)	
	Conclusion based on comparison of correct values of percentage uncertainty	(1)	**(2)**
	Example of calculation		
	Student A %U = $\frac{0.1}{10} \times 100\% = 1\%$		
	Student B %U = $\frac{0.1}{10\pi} \times 100\% = 0.32\%$		
	Therefore Student B has a smaller percentage uncertainty.		
	[Accept 0.5% and 0.16% if uncertainty of 0.05cm used]		
4(b)(i)	Any **TWO** from:		
	Check for zero error to eliminate systematic error	(1)	
	Repeat at different places **and** calculate a mean to reduce the effect of random errors	(1)	
	Avoid squashing the string to reduce the effect of random errors	(1)	**(2)**
4(b)(ii)	mean t = 2.10 mm	(1)	
	Correct uncertainty from calculation of half range shown	(1)	**(2)**
	Example of calculation		
	mean t = (2.15+2.06+2.13+2.08+2.10) mm/5 = 2.104 = 2.10 mm		
	Uncertainty = (2.15–2.06) mm/2 = 0.045 = 0.05 mm		
4(c)(i)	Use of $C = x - \pi t$	(1)	
	Value of C correct to 3 s.f. [e.c.f (b)(ii)]	(1)	**(2)**
	Example of calculation		
	C = 25.8cm – ($\pi \times 0.21$ cm) = 25.8 – 0.66 = 25.1 cm		

4(c)(ii)	Addition of uncertainties shown to minimum 2 s.f. [e.c.f. (b)(ii)] Example of calculation 0.2 cm + 0.005 cm = 0.205 cm	(1)	**(1)**
4(d)	Value of V correct to 3 s.f. [e.c.f. (c)(i)] Use of 2× %U in C and %U in L shown [e.c.f. (c)(i), (c)(ii)] Use of %U to calculate uncertainty in $\frac{C^2L}{4\pi}$ shown Correct uncertainty from addition of final uncertainties Example of calculation $V = (25.1^2 \times 19.9)\ \text{cm}^3/4\pi - 810\ \text{cm}^3 = 998\ \text{cm}^3 - 810\ \text{cm}^3$ $= 188\ \text{cm}^3$ %U in $\frac{C^2L}{4\pi} = (2 \times 0.205\ \text{cm}^3/25.1\ \text{cm}^3)\times 100\% + (0.05\ \text{cm}/19.9\ \text{cm})\times 100\%$ $= 1.63\% + 0.25\% = 1.88\%$ U in $\frac{C^2L}{4\pi} = (998\ \text{cm}^3 \times 1.88\%) = 18.6 = 19\ \text{cm}^3$ U in $V = (19 + 5)\ \text{cm}^3 = 24\ \text{cm}^3$ **Or** Value of V correct to 3 s.f. [e.c.f. (c)(i)] Use of uncertainties to calculate upper or lower limit of V shown [e.c.f. (c)(ii)] Correct upper or lower limit calculated Uncertainty correct from half range of V Example of calculation $V = (25.1^2 \times 19.9)\ \text{cm}^3/4\pi - 810\ \text{cm}^3 = 998\ \text{cm}^3 - 810\ \text{cm}^3$ $= 188\ \text{cm}^3$ Upper limit of $V = \frac{(25.1+0.2)^2\times(19.90+0.05)}{4\pi} - (810 - 5)$ $= 1016 - 805 = 211\ \text{cm}^3$ U = 211 - 188 = 23 cm^3	(1) (1) (1) (1) (1) (1) (1) (1)	**(4)**

4(e)	Calculation of $\rho = \frac{m}{V}$ shown [e.c.f. (d)]	(1)	
	Correct calculation of %U in ρ shown [e.c.f. (d)]	(1)	
	Calculation of relevant upper and/or lower limit shown	(1)	
	Valid conclusion based on comparison [dependent MP3]	(1)	
	<u>Example of calculation</u> ρ = 463 g/188 cm^3 = 2.46 (g cm^{-3}) %U = (1/463 × 100) + (24/188 × 100) = 0.2 + 12.8 = 13% Upper limit = 2.46 × 1.13 = 2.78 (g cm^{-3}) Lower limit = 2.46 × (1–0.13) = 2.14 (g cm^{-3}) As both soda glass and borosilicate lie in the range the container may not be safe to heat.		
	Or		
	Calculation of $\rho = \frac{m}{V}$ shown [e.c.f. (d)]	(1)	
	Correct calculation of %U in ρ shown [e.c.f. (d)]	(1)	
	Correct calculation of %D shown for relevant materials	(1)	
	Valid conclusion based on comparison [dependent MP3]	(1)	
	<u>Example of calculation</u> ρ = 436 g/188 cm^3 = 2.46 (g cm^{-3}) %U = (1/463 × 100) + (24/188 × 100) = 0.2 + 12.8 = 13% Soda glass %D = (2.52–2.46)/2.52 × 100 = 2.38% Borosilicate %D = (2.46–2.23)/2.23 × 100 = 10.3% As both %D are less than the %U we cannot be sure the container is safe to heat.		
	Or		
	Use of uncertainties to calculate maximum or minimum ρ shown	(1)	
	Correct calculation of upper limit of ρ shown	(1)	
	Correct calculation of lower limit of ρ shown	(1)	
	Valid conclusion based on comparison of their values	(1)	**(4)**

	Example of calculation Upper limit of $\rho = \frac{463+1}{188-24} = \frac{464}{164} = 2.83$ (g cm^{-3}) Lower limit of $\rho = \frac{463-1}{188+24} = \frac{462}{212} = 2.18$ (g cm^{-3}) As both soda glass and borosilicate lie in the range the container may not be safe to heat.		
			Total mark for Question 4 = 17