Question Number	Answer	Mark
4(a)(i)	Any **TWO** from: Measure multiple oscillations and divide by the number of oscillations **(1)** Use a (fiducial) marker **(1)** Allow the oscillations to settle **Or** Start timing after a number of oscillations **(1)**	**2**
4(a)(ii)	Mean T = 0.68 (s) **(1)** Calculation using half range shown **Or** Calculation of furthest from mean shown **(1)** Uncertainty in T = 0.02 (s) decimal places consistent with mean **(1)** Example of calculation Mean $T = \frac{(3.43+3.36+3.28+3.49)s}{5\times4} = \frac{13.56s}{20} = 0.678 = 0.68$ (s) Uncertainty = $\frac{3.49s-3.28s}{5\times2} = \frac{0.21}{10} = 0.021 = 0.02$ (s)	**3**
4(b)	Vernier calipers will have resolution of 0.1 mm **Or** Vernier calipers will have an uncertainty of 0.05 mm **(1)** So the percentage uncertainty is 0.25 % which is small **(1)** [Do not accept precision or accuracy for resolution] Example of calculation %U in Vernier calipers = $\frac{0.05mm}{20mm} \times 100 = 0.25$ %	**2**

4(c)(i)	Use of $T = \sqrt{\frac{16\pi m}{D^2 \rho g}}$	**(1)**	
	ρ = 1190 (kg m^3)	**(1)**	**2**
	Example of calculation $\rho = \frac{16\pi m}{D^2 T^2 g} = \frac{16\pi \times 48.95\times10^{-3}\ \text{kg}}{(2.38\times10^{-2}\text{m})^2 \times (0.61\text{s})^2 \times 9.81\text{ms}^{-2}} = \frac{2.46\ \text{kg}}{2.07\times10^{-3}\ \text{m}^3}$ = 1190 (kg m^3)		
4(c)(ii)	**EITHER**	**(1)**	
		(1)	
	Uses 2 × %U in D [Allow 2 × $\frac{\Delta d}{d}$]	**(1)**	
	Uses 2 × %U in T [Allow 2 × $\frac{\Delta T}{T}$]		
	%U in ρ = 4.1 (%) Accept 3 sig figs		
	Example of calculation %U in $D^2 = 2 \times \frac{0.01\text{cm}}{2.38\text{cm}} \times 100 = 0.84$ % %U in $T^2 = 2 \times \frac{0.01\text{s}}{0.61\text{s}} \times 100 = 3.28$ % %U in ρ = 0.84 % + 3.28 % = 4.12 %		
	OR		
	Calculation of maximum or minimum ρ	**(1)**	
	Calculation of U in ρ using half range shown	**(1)**	
	%U in ρ = 4.1 (%) Accept 3 sig figs	**(1)**	**3**
	Example of calculation Maximum $\rho = \frac{16\pi m}{D^2 T^2 g} = \frac{16\pi \times 48.95\times10^{-3}\ \text{kg}}{(2.37\times10^{-2}\text{m})^2 \times (0.60\text{s})^2 \times 9.81\text{ms}^{-2}} = \frac{2.46\ \text{kg}}{1.98\times10^{-3}\ \text{m}^3}$ = 1242 (kg m^3) Minimum $\rho = \frac{16\pi m}{D^2 T^2 g} = \frac{16\pi \times 48.95\times10^{-3}\ \text{kg}}{(2.39\times10^{-2}\text{m})^2 \times (0.62\text{s})^2 \times 9.81\text{ms}^{-2}} = \frac{2.46\ \text{kg}}{2.15\times10^{-3}\ \text{m}^3}$ = 1144 (kg m^3) U in $\rho = \frac{(1242-1144)\text{kgm}^{-3}}{2}$ = 49 (kg m^3) %U = $\frac{49\text{kgm}^{-3}}{1190\text{kgm}^{-3}} \times 100 = 4.1$ (%)		

4(c)(iii)	**EITHER**	**(1)**	
	Correct value of relevant limit of calculated density using %U (e.c.f. (c)(i), (c)(ii))	**(1)**	
	Conclusion based on comparison of limit to density of glycerol MP2 dependent MP1		
	Example of calculation Upper limit of $\rho = 1190 \times (1 + 0.041) = 1239$ (kg m^{-3}) As the upper limit is lower than 1260 kg m^{-3} then the liquid may not be glycerol. ['Show that' value gives upper limit $\rho = 1200 \times (1 + 0.04) = 1248$ (kg m^{-3})]		
	OR	**(1)**	
	Correct calculation of %D shown (e.c.f. (c)(i), (c)(ii))	**(1)**	
	Conclusion based on comparison of %D and %U MP2 dependent MP1		
	Example of calculation $\%D = \frac{(1260-1190)\text{kgm}^{-3}}{1260\text{kgm}^{-3}} \times 100 = 5.6\ \%$ As % D for greater than the %U then the liquid may not be glycerol. ['Show that' value gives $\%D = \frac{(1260-1200)\text{kgm}^{-3}}{1260\text{kgm}^{-3}} \times 100 = 4.8\ \%$]		
	OR	**(1)**	
	Correct value of relevant limit using uncertainties in D and T	**(1)**	**2**
	Conclusion based on comparison of limit to density of glycerol MP2 dependent MP1		
	Example of calculation Upper limit of $\rho = \frac{16\pi m}{D^2T^2g} = \frac{16\pi \times 48.95\times10^{-3}\text{ kg}}{(2.37\times10^{-2}\text{m})^2 \times (0.60\text{s})^2 \times 9.81\text{ms}^{-2}} = \frac{2.46\text{ kg}}{1.98\times10^{-3}\text{ m}^3}$ $= 1242$ (kg m^3) As the upper limit is lower than 1260 kg m^{-3} then the liquid may not be glycerol.		
	Total for question 4		**14**