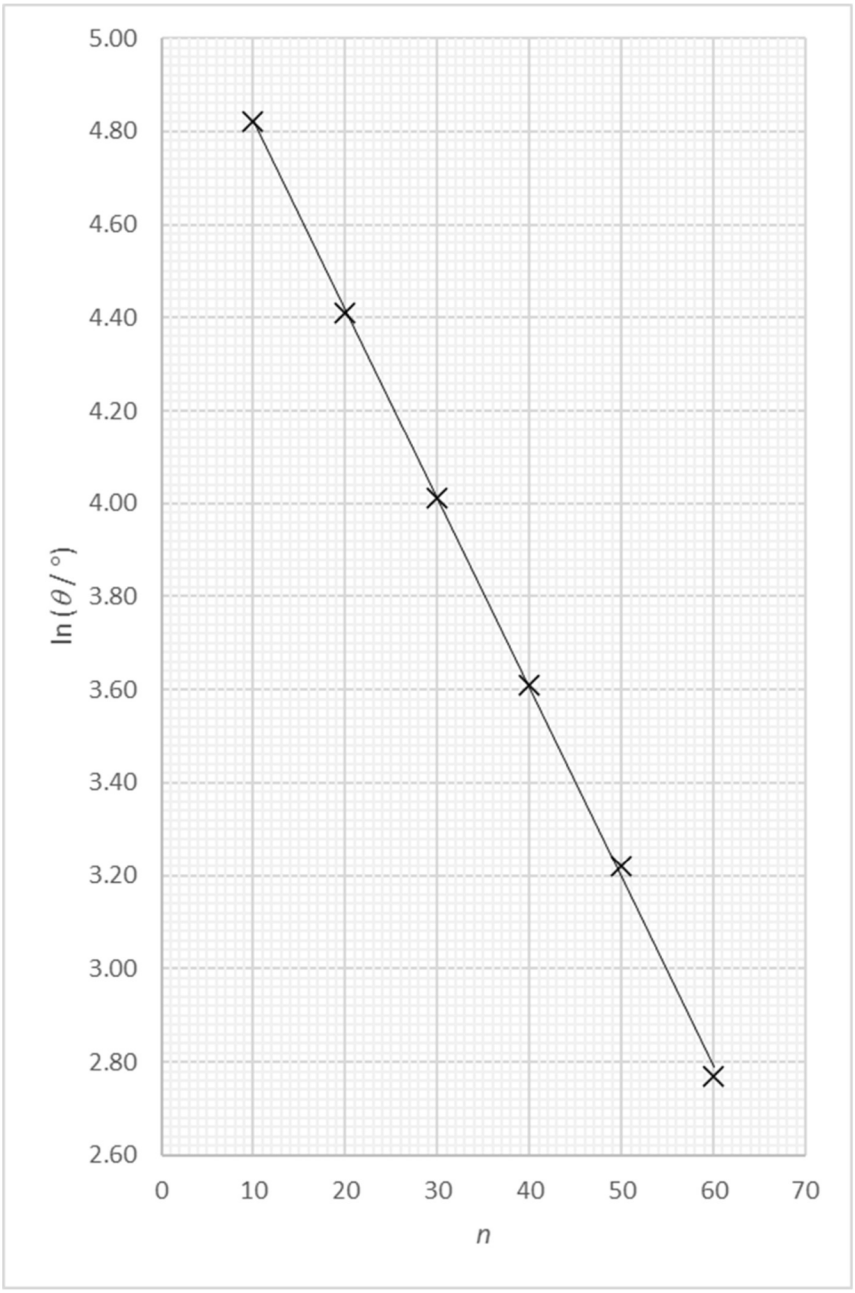
n	θ / °	ln (θ / °)
10	124	4.82
20	82	4.41
30	55	4.01
40	37	3.61
50	25	3.22
60	16	2.77



Question Number	Answer		Mark
4(a)(i)	Any **PAIR** from: Repeat at different orientations and calculate a mean **(1)** To reduce (the effect of) random error **(1)** **Or** Check and correct for zero error Accept suitable method **(1)** To eliminate systematic error **(1)** MP2 dependent MP1		**2**
4(a)(ii)	Mean d = 8.54 (mm) **(1)** Calculation using half range shown **Or** Calculation of furthest from mean **(1)** Uncertainty in d = 0.02 (mm) d.p. consistent with mean **(1)** Example of calculation Mean d = (8.53 + 8.56 + 8.55 + 8.53) / 4 = 34.17 / 4 = 8.54 (mm) Uncertainty = (8.56 – 8.53) / 2 = 0.03 / 2 = 0.015 = 0.02 (mm)		**3**
4(b)(i)	Use of 2 × %U in d shown **Or** Use of $2 \times \frac{\Delta d}{d}$ shown **(1)** Calculation of U in d^2 shown **(1)** U in d^2= 1.3 (mm^2) Accept 3 sig figs **(1)** Example of calculation %U in $d^2 = 2 \times \frac{0.06}{10.70} \times 100 = 1.1$ % U in d^2= (10.70)^2 mm^2 × 1.1 % = 1.26 (mm^2) **Or** Uses uncertainty in d to calculate minimum or maximum d^2 Calculation of U in d^2 using half range shown **(1)** U in d^2= 1.3 (mm^2) Accept 3 sig figs **(1)** Example of calculation Maximum d^2 = (10.70 + 0.06)^2 = 10.76^2 = 115.8 (mm^2) Minimum d^2 = (10.70 – 0.06)^2 = 10.64^2 = 113.2 (mm^2) U in $d^2 = \frac{115.8-113.2}{2} = \frac{2.6}{2}$ = 1.3 (mm^2)	**(1)**	**3**

4(b)(ii)	Use of $A = \frac{\pi}{4}(s^2 - d^2)$	**(1)**	
	Addition of uncertainties in s^2 and d^2 e.c.f. 4(b)(i)	**(1)**	
	Calculation of U in A using factor of $\frac{\pi}{4}$ shown	**(1)**	
	%U in A = 0.43 % Accept 3 sig figs	**(1)**	
	Accept use of U in d^2 of 1mm^2 to give 0.39%		
	<u>Example of calculation</u> $A = \frac{\pi}{4}(s^2 - d^2) = \frac{\pi}{4}(881 - 114) = \frac{\pi}{4} \times 766 = 602$ mm^2 U in $A = \frac{\pi}{4}(2 + 1.3) = \frac{\pi}{4} \times 3.3 = 2.6$ mm^2 %U in $A = \frac{2.6}{602} \times 100 = 0.43$ %		
	Or		
	Use of $A = \frac{\pi}{4}(s^2 - d^2)$	**(1)**	
	Correct use of uncertainties to calculate maximum or minimum A e.c.f. 4(b)(i)	**(1)**	
	Calculation of U in A from half range shown	**(1)**	
	%U in A = 0.42 % Accept 3 sig figs	**(1)**	**4**
	<u>Example of calculation</u> $A = \frac{\pi}{4}(s^2 - d^2) = \frac{\pi}{4}(881 - 114) = \frac{\pi}{4} \times 767 = 602$ mm^2 Max $A = \frac{\pi}{4}(s^2 - d^2) = \frac{\pi}{4}((881 + 2) - (114 - 1)) = \frac{\pi}{4} \times 770 = 605$ mm^2 Min $A = \frac{\pi}{4}(s^2 - d^2) = \frac{\pi}{4}((881 - 2) - (114 + 1)) = \frac{\pi}{4} \times 763 = 600$ mm^2 U in $A = \frac{605-600}{2} = 2.5$ mm^2 %U in $A = \frac{2.5}{602} \times 100 = 0.42$ %		
4(c)	Both readings would have the same uncertainty	**(1)**	
	(So) the percentage uncertainty (in the mass) is reduced **Or** %U for mass of 10 rings = 0.8% and %U for mass of one ring = 8%	**(1)**	**2**
4(d)(i)	Use of $\rho = \frac{m}{xA}$	**(1)**	
	ρ = <u>7.46</u> (g cm^{-3})	**(1)**	**2**
	<u>Example of calculation</u> $\rho = \frac{63}{1.403 \times 6.02} = 7.46$ (g cm^{-3})		

4(d)(ii)	%U in ρ = 1.5 % Accept 1, 2 or 3 sig figs **(1)** Correct calculation of relevant limit using %U shown e.c.f. (d)(i) **(1)** Conclusion based on comparison of limit and range **(1)** MP3 dependent MP2 Example of calculation %U in $\rho = \frac{0.5}{63} \times 100 + \frac{0.04}{14.03} \times 100 + 0.4 = 0.8\ \% + 0.3\ \% + 0.4\ \% = 1.5\ \%$ Upper limit of $\rho = 7.46 \times (1 + 0.015) = 7.57$ (g cm^{-3}) As the upper limit is higher than 7.48 g cm^{-3} then the ring could be made from stainless steel. **Or** %U in ρ = 1.5 % Accept 1, 2 or 3 sig figs **(1)** Correct calculation of relevant %D shown e.c.f. (d)(i) **(1)** Conclusion based on comparison of %D and %U **(1)** MP3 dependent MP2 Example of calculation %U in $\rho = \frac{0.5}{63} \times 100 + \frac{0.04}{14.03} \times 100 + 0.4 = 0.8\ \% + 0.3\ \% + 0.4\ \% = 1.5\ \%$ %D = $\frac{7.48-7.46}{7.48} \times 100 = 0.3\ \%$ As % D for the lower value is less than the %U then the ring could be made from stainless steel. **Or** Use of $\rho = \frac{m}{xA}$ and uncertainties to calculate maximum or minimum ρ **(1)** Correct calculation of relevant limit shown e.c.f. (d)(i) **(1)** Conclusion based on comparison of relevant limit and range **(1)** MP3 dependent MP2 Example of calculation Maximum $\rho = \frac{63+0.5}{(1.403-0.004)\times(6.02-0.4\%)} = \frac{63.5}{1.399\times6.00} = \frac{63.5}{8.39} = 7.56$ (g cm^{-3}) As the maximum ρ is higher than 7.48 g cm^{-3} then the ring could be made from stainless steel. Note minimum ρ = 7.35 (g cm^{-3})		**3**
	Total for question 4		**19**