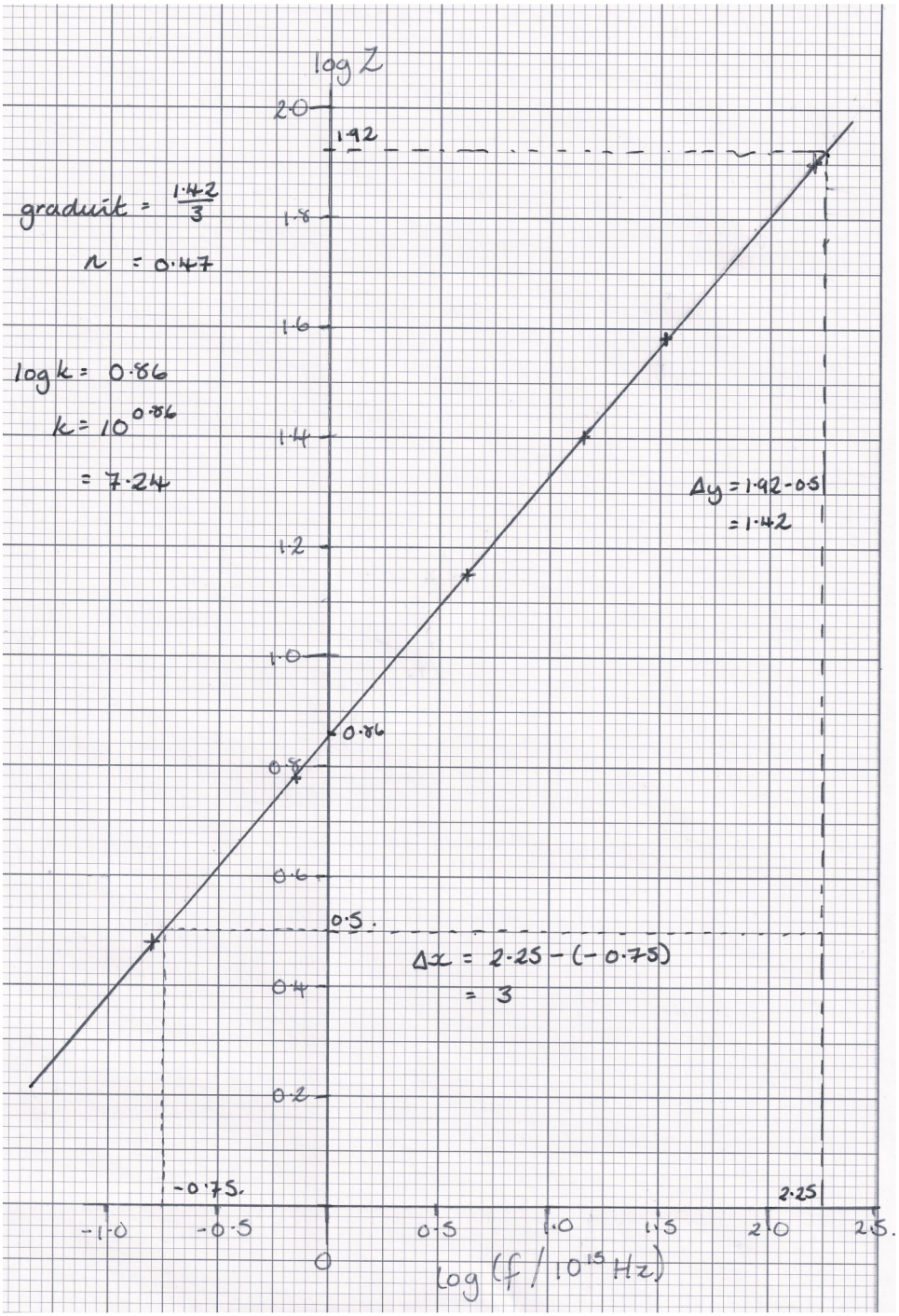
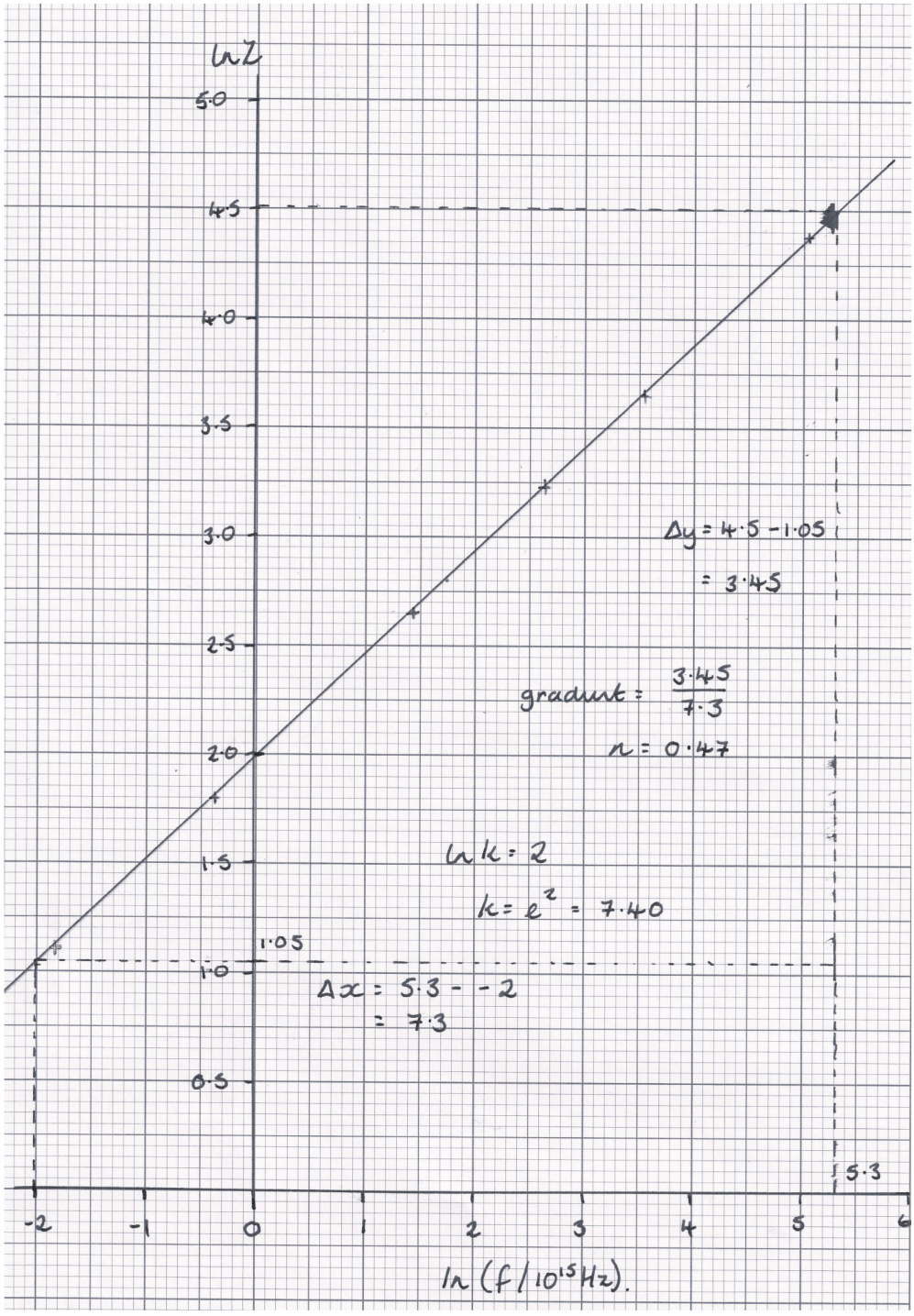
Element	Z	$f / 10^{15}$ Hz	log Z	log ($f / 10^{15}$ Hz)
Li	3	0.16	0.48	–0.80
C	6	0.69	0.78	–0.16
Si	14	4.19	1.15	0.62
Mn	25	13.82	1.40	1.14
Sr	38	33.98	1.58	1.53
Hg	80	154.64	1.90	2.19



Element	Z	$f / 10^{15}$ Hz	ln Z	ln ($f / 10^{15}$ Hz)
Li	3	0.16	1.10	–1.83
C	6	0.69	1.79	–0.37
Si	14	4.19	2.64	1.43
Mn	25	13.82	3.22	2.63
Sr	38	33.98	3.64	3.53
Hg	80	154.64	4.38	5.04



Question Number	Answer	Mark
4 (a)(i)	Digital calipers have a smaller resolution [Accept converse] (1) Calculation of percentage uncertainty using (half) resolution shown (1) %U for Vernier = 0.8% **and** %U digital = 0.08% (1) Hence the percentage uncertainty for digital calipers will be smaller (1) <u>Example of calculation</u> %U in Vernier reading = 0.05 / 6.6 × 100 = 0.8 % %U in digital reading = 0.005 / 6.58 × 100 = 0.08 %	**4**
4 (a)(ii)	Any **PAIR** from: Repeat at different orientations and calculate a mean (1) Hence reduces (the effect of) <u>random errors</u> (1) **Or** Check and correct for zero error [Accept suitable method] (1) Hence eliminates <u>systematic error</u> (1)	**2**
4 (a)(iii)	Mean d = <u>6.55</u> (mm) (1) Calculation using half range shown [Accept furthest from mean] (1) Uncertainty in d = <u>0.03</u> (mm) (1) <u>Example of calculation</u> Mean d = (6.57 + 6.58 + 6.54 + 6.52) / 4 = 26.21 / 4 = 6.55 (mm) Uncertainty = (6.58 – 6.52) / 2 = 0.06 / 2 = 0.03 (mm)	**3**

4 (b)	Use of 2 × %U in s or d shown Calculation of U in s^2 or d^2 using 2 × %U shown Addition of U in s^2 and U in d^2 shown U = 0.011 (cm^2) <u>Example of calculation</u> %U in s^2= 2 × (0.02 / 16.83) × 100 = 2 × 0.12% = 0.24 % U in $s^2 = 1.683^2 \times 0.24\ \% = 6.80 \times 10^{-3}\ cm^2$ %U in d^2= 2 × (0.04 / 8.55) × 100 = 2 × 0.47% = 0.94 % U in $d^2 = 0.855^2 \times 0.94\ \% = 6.87 \times 10^{-3}\ cm^2$ U in $A = (6.80 \times 10^{-3} \times \sqrt{3}) / 2 + (6.87 \times 10^{-3} \times \pi) / 4$ $= 5.89 \times 10^{-3} + 5.40 \times 10^{-3} = 0.011\ cm^2$ **Or** Use of correct absolute uncertainties for s and d Use of maximum and minimum values to calculate limit of A shown Correct value of maximum or minimum A Subtraction to obtain uncertainty in A approximately 0.01 cm^2 MP4 dependent on MP3 <u>Example of calculation</u> minimum $s^2 = (1.683 - 0.002)^2 = 1.681\ cm^2$ maximum $d^2 = (0.855 + 0.004)^2 = 0.738\ cm^2$ minimum $A = \sqrt{3} \times 1.681/2 - \pi \times 0.738/4 = 1.867\ cm^2$ uncertainty in $A = 1.88 - 1.867 = 0.013\ cm^2$	(1) (1) (1) (1)	**4**
4 (c)(i)	Use of $\rho = m / Ax$ $\rho = 6.91\ g\ cm^{-3}$ [3 s.f. only] [Accept 6.92 g cm^{-3}] <u>Example of calculation</u> $\rho = 10.3 / (1.88 \times 0.792) = 10.3 / 1.49 = 6.91\ g\ cm^{-3}$	(1) (1)	**2**

4 (c)(ii)	Calculation of %U in ρ shown	(1)	
	Correct calculation of relevant limit using %U shown [e.c.f. (c)(i)]	(1)	
	Conclusion based on comparison of limit and calculated ρ	(1)	
	[MP3 dependent MP2]		
	<u>Example of calculation</u>		
	%U in ρ = (0.1 / 10.3) × 100 + (0.01 / 1.88) × 100 + (0.03 / 7.92) × 100		
	= 0.97 % + 0.53 % + 0.38 % = 1.88 %		
	Upper limit of ρ = 6.91 × (1 + 0.0188) = 7.04 g cm^{-3}		
	As the upper limit is lower than 7.85 g cm^{-3} the hexagonal metal nut is not made from steel.		
	Or		
	Use of maximum or minimum values shown	(1)	
	Maximum ρ = 7.05 g cm^{-3} **Or** Minimum ρ = 6.79 g cm^3	(1)	
	Conclusion based on comparison of maximum or minimum ρ with calculated ρ	(1)	
	[MP3 dependent MP2]		
	<u>Example of calculation</u>		
	Maximum ρ = (10.3 + 0.1) / ((0.792 – 0.003) × (1.88 – 0.01) = 7.05 g cm^{-3}		
	As the maximum value is lower than 7.85 g cm^{-3} the hexagonal metal nut is not made from steel.		
	Or		
	Calculation of %U in ρ shown	(1)	
	Correct calculation of relevant %D shown [e.c.f. (c)(i)]	(1)	
	Conclusion based on comparison of %D and %U	(1)	**3**
	[MP3 dependent MP2]		
	<u>Example of calculation</u>		
	%U in ρ = (0.1 / 10.3) × 100 + (0.01 / 1.88) × 100 + (0.03 / 7.92) × 100		
	= 0.97 % + 0.53 % + 0.38 % = 1.88 %		
	%D = (7.85 – 6.91) / 7.85 × 100 = 12 %		
	As % D for lower value is greater than the %U then the hexagonal metal nut is not made from steel.		
	Total for question 4		**18**