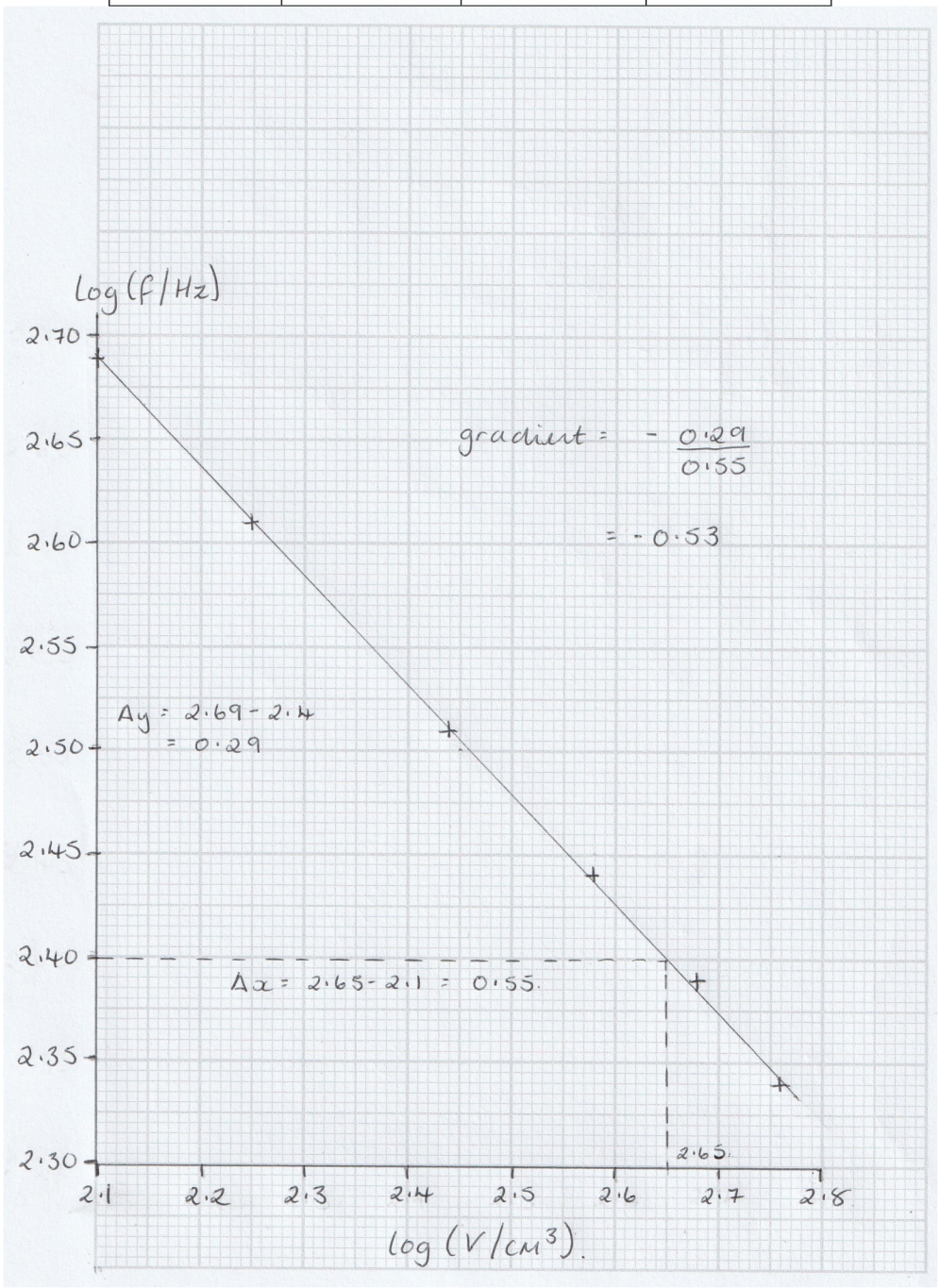
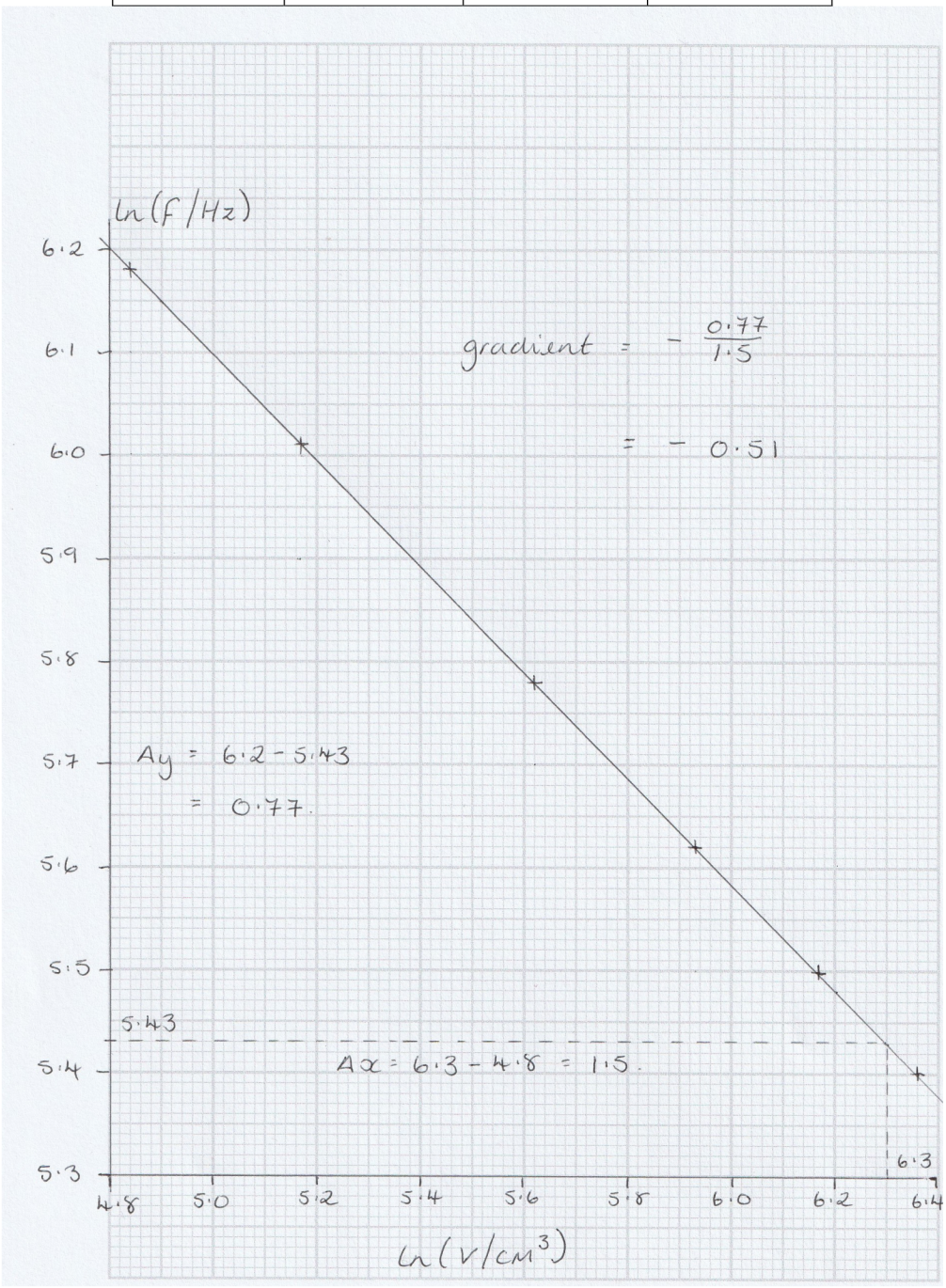
V / cm^3	f / Hz	log (V / cm^3)	log (f / Hz)
576	221	2.76	2.34
476	244	2.68	2.39
376	275	2.58	2.44
276	323	2.44	2.51
176	408	2.25	2.61
126	485	2.10	2.69



V / cm^3	f / Hz	ln (V / cm^3)	ln (f / Hz)
576	221	6.36	5.40
476	244	6.17	5.50
376	275	5.93	5.62
276	323	5.62	5.78
176	408	5.17	6.01
126	485	4.84	6.18



Question Number	Answer	Mark
4 (a)(i)	Any **TWO** from: Ensure the metre rule is vertical using a set square Accept alternative valid methods (1) Ensure the end of the rod is close to the metre rule **Or** use a set square to read off the values (1) Take readings perpendicular to the scale (to avoid parallax) (1)	**2**
4 (a)(ii)	The uncertainty of a single reading is half the resolution of the metre rule, (which is 0.5 mm) (1) As the two readings are subtracted, the uncertainties are added (1)	**2**
4 (b)(i)	Micrometer screw gauge (with a resolution of 0.01mm) (Accept digital caliper) (1) As this would produce an uncertainty of 0.25% which is small (1)	**2**
4 (b)(ii)	One **PAIR** from: Repeat at different orientations **and** calculate a mean (1) To reduce the effect of <u>random errors</u> (1) Check (and correct) for zero error (1) To eliminate <u>systematic error</u> (1)	**2**
4 (b)(iii)	Mean value of d = <u>2.35</u> (mm) (1) Calculation from half range shown to give uncertainty of 0.02 (mm) (1) <u>Example of calculation</u> Mean d = (2.35 + 2.37 + 2.34 + 2.34 + 2.33) mm / 5 = 11.74 mm / 5 = 2.348 mm = 2.35 mm Uncertainty = (2.37 – 2.33) mm /2 = 0.04 mm/2 = 0.02 mm	**2**
4 (c)	Use of $G = (32mglx^2) / (\pi\, yd^4)$ shown (1) Correct value of G given to 2 or 3 s.f. e.c.f. (b)(iii) (1) Bald answer scores 0 Accept value of 1.5×10^{11} (N m^{-2}) if d = 2 mm used <u>Example of calculation</u> $G = \frac{32 \times 0.1\text{kg} \times 9.81\text{ N kg}^{-1} \times 0.589\text{ m} \times (0.103\text{ m})^2}{3.14159 \times 0.026\text{ m} \times (2.35 \times 10^{-3}\text{ m})^4}$ $= 0.196\text{ N m}^3 / 2.49 \times 10^{-12}\text{ m}^5$ $= 7.87 \times 10^{10}$ (N m^{-2}) $= 7.9 \times 10^{10}$ (N m^{-2})	**2**

4 (d)	Use of 2× %U in x **Or** 4× %U in d shown		(1)
	Calculation of correct value of %U in G	e.c.f. (b)(iii)	(1)
	Correct value of relevant limits from %U	e.c.f. (c)	(1)
	Valid conclusion based on comparison of relevant limits with data		(1)
	Example of calculation %U = (0.1 / 58.9) × 100 + 2 × (0.1 / 10.3) × 100 + (1 / 26) × 100 + 4 × (0.02 / 2.35) × 100 = 0.17% + 2 × 0.97% + 3.85% + 4 × 0.85% = 0.17% + 1.94% + 3.85% + 3.40% = 9.36% = 9.4% Upper limit = 78.7×10^9 N m^2 × (1+0.094) = 86.1×10^9 N m^2 Lower limit = 78.7×10^9 N m^2 × (1 – 0.094) = 71.3×10^9 N m^2 As both values fall within this range, the student cannot determine which type of steel the rod is made from.		
	Or		
	Use of uncertainties to calculate maximum or minimum shown		(1)
	Calculation of correct value of upper limit		(1)
	Calculation of correct value of lower limit		(1)
	Valid conclusion based on comparison of relevant limit with data		(1)
	Example of calculation Upper limit $G = \frac{32 \times 0.1\text{kg} \times 9.81\text{Nkg}^{-1} \times (0.589+0.001)\text{m} \times ((0.103+0.001)\text{m})^2}{3.14159 \times (0.026–0.01)\text{ m} \times ((2.35–0.02) \times 10^{-3}\text{ m})^4}$ = 0.200 N m^3 / 2.31×10^{-12} m^5 = 8.68×10^{10} (N m^{-2}) Lower limit $G = \frac{32 \times 0.1\text{kg} \times 9.81\text{Nkg}^{-1} \times (0.589–0.001)\text{m} \times ((0.103–0.001)\text{m})^2}{3.14159 \times (0.026+0.01)\text{ m} \times ((2.35+0.02) \times 10^{-3}\text{ m})^4}$ = 0.192 N m^3 / 2.68×10^{-12} m^5 = 7.16×10^{10} (N m^{-2}) As both values fall within this range, the student cannot determine which type of steel the rod is made from.		
	Or		(1)
	Use of 2× %U in x **Or** 4× %U in d shown		(1)
	Calculation of correct value of %U in G	e.c.f. (b)(iii)	(1)
	Correct calculation of relevant %D shown	e.c.f. (c)	(1)
	Valid conclusion based on comparison of relevant %D with %U		
	Example of calculation %U = (0.1 / 58.9) × 100 + 2 × (0.1 / 10.3) × 100 + (1 / 26) × 100 + 4 × (0.02 / 2.35) × 100		

4

	= 0.17% + 2 × 0.97% + 3.85% + 4 × 0.85% = 0.17% + 1.94% + 3.85% + 3.40% = 9.36% = 9.4% %D for structural steel = (78.7 – 79.3)/79.3 × 100 = 0.76 % %D for carbon steel = (78.7 – 77)/77 × 100 = 2.3% As % D for both structural and carbon steel are less than the %U, the student cannot determine which type of steel the rod is made from.	
	Total for question	**16**