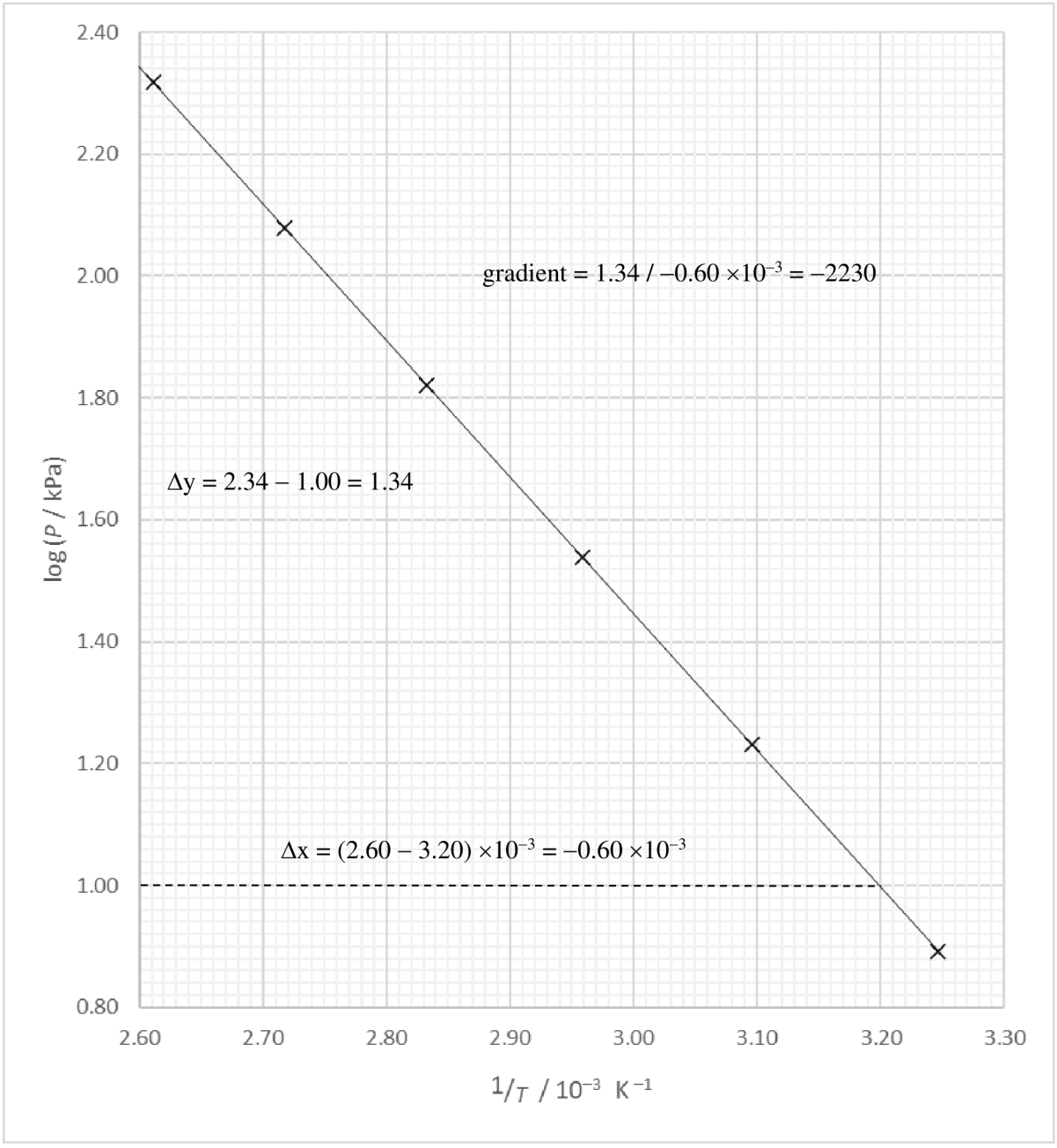
P / kPa	T / K	$\frac{1}{T}$ / K^{-1}	log (P / kPa)
7.8	308	0.00325	0.89
17.0	323	0.00310	1.23
34.6	338	0.00296	1.54
66.1	353	0.00283	1.82
120.1	368	0.00272	2.08
208.1	383	0.00261	2.32



Question Number	Answer		Mark
4(a)(i)	**Either** Repeat at different orientations (along the wire) **and** calculate a mean To reduce the effect of <u>random</u> errors **Or** Check **and** correct for zero error (on micrometer screw gauge) To eliminate <u>systematic</u> error MP2 dependent on MP1 [Allow MP2 if MP1 partially correct]	**(1)** **(1)** **(1)** **(1)**	**2**
4(a)(ii)	Mean d = <u>0.31</u> (mm) Calculation using half range shown **Or** Calculation of furthest from mean shown Uncertainty in d = 0.02 (mm) Decimal places consistent with the calculated mean MP3 dependent on MP2 <u>Example of calculation</u> Mean d = (0.31 + 0.32 + 0.31 + 0.33 + 0.30) / 5 = 1.57 / 5 = 0.314 = 0.31 (mm) Uncertainty = (0.33 – 0.30) / 2 = 0.03 / 2 = 0.015 = 0.02 (mm)	**(1)** **(1)** **(1)**	**3**
4(b)(i)	Use of $A = \pi d^2/4$ **and** $R = V/I$ Use of $R = \rho L/A$ $\rho = 4.6 \times 10^{-7}$ (Ω m) <u>Example of calculation</u> $A = \pi \times (0.22\times10^{-3}\ \text{m})^2 / 4 = 3.80 \times 10^{-8}\ \text{m}^2$ $R = V / I = 4.990\ \text{V} / 0.4570\ \text{A} = 10.9\ \Omega$ $\rho = RA / L = 10.9\ \Omega \times 3.80 \times 10^{-8}\ \text{m}^2 / 0.894\ \text{m} = 4.6 \times 10^{-7}$ (Ω m)	**(1)** **(1)** **(1)**	**3**

4(b)(ii)	Use of 2 × %U in d shown [Accept 2 × $\Delta d/d$ if converted to %U] **(1)** Addition of %U for all variables shown **(1)** %U = 9.4 (%) [Accept answers that round to 9%] **(1)** <u>Example of calculation</u> %U in d = (0.01 / 0.22) × 100 = 4.55 % %U in V = (0.005 / 4.990) × 100 = 0.10 % %U in L = (0.1 / 89.4) × 100 = 0.11 % %U in I = (0.0005 / 0.4570) × 100 = 0.11 % %U in ρ = (2 × 4.55) + 0.10 + 0.11 + 0.11 = 9.42 = 9.4% **Or** Use of uncertainties to calculate maximum ρ **Or** **(1)** Use of uncertainties to calculate minimum ρ **(1)** Calculation of uncertainty in ρ using maximum and minimum ρ **(1)** %U = 9.3 (%) [Accept answers that round to 9%] <u>Example of calculation</u> $A_{max} = \pi \times (0.23\times10^{-3}\text{ m})^2 / 4 = 4.15 \times 10^{-8}\text{ m}^2$ $A_{min} = \pi \times (0.21\times10^{-3}\text{ m})^2 / 4 = 3.16 \times 10^{-8}\text{ m}^2$ $R_{max} = V_{max} / I_{min} = 4.995\text{ V} / 0.4565\text{ A} = 10.9\ \Omega$ $R_{min} = V_{min} / I_{max} = 4.985\text{ V} / 0.4575\text{ A} = 10.9\ \Omega$ $\rho_{max} = R_{max} A_{max} / L_{min} = 10.9\ \Omega \times 4.15 \times 10^{-8}\text{ m}^2 / 0.893\text{ m}$ $= 5.07 \times 10^{-7}\ (\Omega\text{ m})$ $\rho_{min} = R_{min} A_{min} / L_{max} = 10.9\ \Omega \times 3.46 \times 10^{-8}\text{ m}^2 / 0.895\text{ m}$ $= 4.21 \times 10^{-7}\ (\Omega\text{ m})$ U in $\rho = (5.07 \times 10^{-7} - 4.21 \times 10^{-7}) / 2 = 0.43 \times 10^{-7}\ (\Omega\text{ m})$ %U in $\rho = 0.43 \times 10^{-7} / 4.6 \times 10^{-7} \times 100 = 9.34 = 9.3$ %	**3**
4(c)	Use of an uncertainty of 0.05 Ω in value of R_1 or R_2 **(1)** Use of U = 2× (U in R_2 + U in R_1) shown **Or** Use of maximum and minimum values shown **(1)** %U = 1.8 (%) **(1)** <u>Example of calculation</u> U = 2 × (0.05 + 0.05) = 2× 0.1 = 0.2 %U = (0.2 / 11.4) × 100 = 1.8 %	**3**

4(d)	Upper limit of $\rho = 5.0$ ($\times 10^{-7}$ Ω m)	**(1)**	
	Lower limit of $R_L = 11.2$ (Ω)	**(1)**	
	Conclusion based on comparison of limits	**(1)**	
	[MP3 dependent MP1 or MP2]		
	<u>Example of calculation</u>		
	Upper limit $\rho = 4.6 \times 10^{-7} \times (1 + 0.09) = 5.0 \times 10^{-7}$ Ω m		
	Lower limit $R_L = 11.4 \times (1–0.02) = 11.2$ Ω		
	Therefore both values fall in the range (confirming metal is constantan).		
	Or		
	%D for $\rho = 6.1\%$		
	%D for $R_L = 1.8\%$	**(1)**	
	Conclusion based on comparison of %D and %U	**(1)**	
	[MP3 dependent MP1 or MP2]	**(1)**	**3**
	<u>Example of calculation</u>		
	%D for $\rho = (4.9 – 4.6) / 4.9 \times 100 = 6.1$ %		
	%D for $R_L = (11.4 – 11.2) / 11.2 \times 100 = 1.8$ %		
	Therefore both %D are less than %U (confirming metal is constantan).		
	Total for question 4		**17**