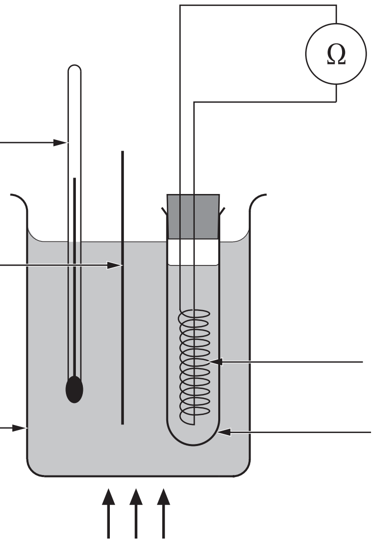
Examiner only

Data Analysis Task

A Physics student carried out an experiment to find the temperature coefficient of resistance, α, of copper. The following apparatus was used.



The resistance of the copper coil was recorded as the water bath was heated from 10 to 80 °C. Repeat readings were recorded as the water cooled back down to 10 °C.

Temperature, θ / °C	Resistance heating, R_θ / Ω	Resistance cooling, R_θ / Ω	Mean resistance, R_θ / Ω	Absolute uncertainty / Ω
10 ± 1	4.89	5.05		
20 ± 1	5.12	5.24		
30 ± 1	5.26	5.34		
40 ± 1	5.40	5.60		
50 ± 1	5.62	5.80		
60 ± 1	5.80	6.00		
70 ± 1	5.97	6.13		
80 ± 1	6.19	6.31		

(a) Complete the final two columns of the table. [2]

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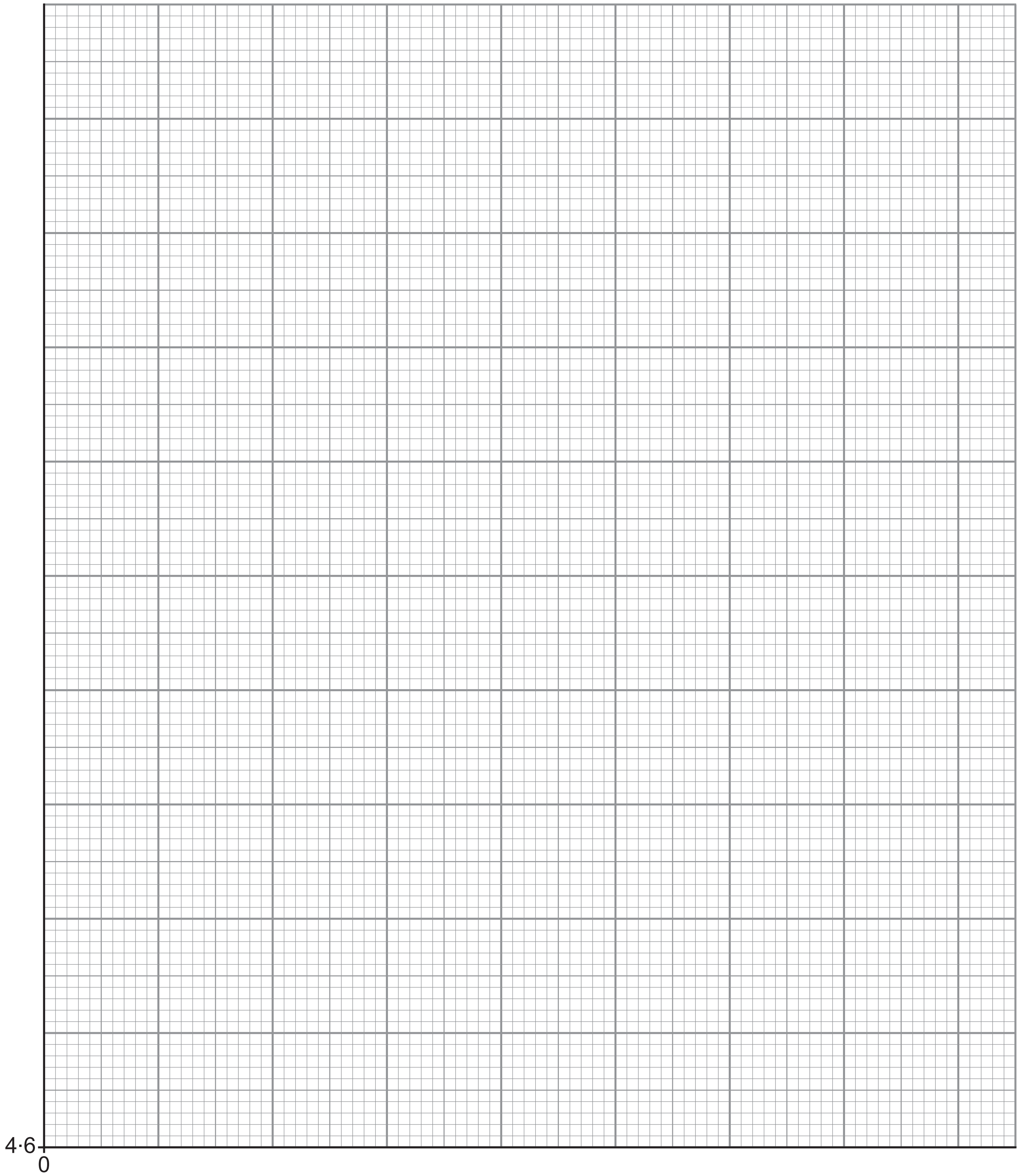
(b) Plot a graph of mean resistance, R_θ, (on the vertical axis) against temperature, θ, (on the horizontal axis). Include error bars on **both** axes, and draw a line of maximum gradient and a line of minimum gradient. [5]



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(c) The temperature coefficient of resistance, α, of copper can be found using the equation:

$$R_\theta = \alpha R_0 \theta + R_0$$

where:

R_0 = Resistance at 0 °C

R_θ = Resistance at temperature θ °C

θ = Temperature /°C

α = Temperature coefficient of resistance

Explain whether or not your graph is in agreement with the above equation. [3]

(d) (i) Calculate the maximum and minimum gradients for your graph. [3]

(ii) Hence determine the mean gradient and its **percentage** uncertainty. [2]

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(e) (i) Calculate the mean value of the intercept along with its **percentage** uncertainty. State in words what this value represents. [3]

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(ii) Using your calculations in parts *(d)*(ii) and *(e)*(i), calculate the temperature coefficient of resistance, α, of copper. Include an appropriate unit for α. [4]

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(iii) State a value for the temperature coefficient of resistance, α, of copper to a suitable number of significant figures along with its **absolute** uncertainty. [3]

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END OF PAPER

DATA ANALYSIS TASK – Mark Scheme

Question		Marking details	Marks Available
(a)		(see table below) 1 mark for each correct column. Note all numbers must be identical to those given in the table including any zeros - *but accept 5.5 ± 0.1 and 5.9 ± 0.1.	2
(b)		Axes labelled with units and suitable scales (not involving awkward factors, e.g. 3 / over ½ each axis used). (1) All points plotted correctly to within ½ small square division. (2) (–1 for each incorrect plot). All error bars plotted correctly. (1) Correct maximum gradient and minimum gradient lines consistent with the error bars. (1) See exemplification on pages 4-8 for additional guidance on marking this section.	5
(c)		It is a straight-line graph. (1) **Positive** intercept (on the resistance axis). (1) For the 3rd mark: **Either:** Possible to draw a straight line through all the error bars / boxes. (1) Accept data points **Or** Has a positive gradient. (1) N.B. There is no mark for just "yes it is in agreement". **Subtract one mark** for contradictory conclusion e.g. "not in agreement" because a straight line with positive intercept through all error bars → 2 marks	3

Table for *(a)*:

Temperature, θ /°C	Mean resistance, R_θ/Ω	Absolute uncertainty /Ω
10 ± 1	4.97	0.08
20 ± 1	5.18	0.06
30 ± 1	5.30	0.04
40 ± 1	5.50*	0.10*
50 ± 1	5.71	0.09
60 ± 1	5.90*	0.10*
70 ± 1	6.05	0.08
80 ± 1	6.25	0.06
	(1)	(1)

Question		Marking details	Marks Available
(d)	(i)	Large triangles used (should be close to the extremities of the lines) or 2 equivalent suitable points clearly indicated on each line. (1) Both gradients calculated correctly (ignore unit and significant figures) (1 + 1) Allow **ecf** for incorrect max/min lines. Exemplar values – values must be in agreement with candidate's graph. Max gradient = $\frac{6.33 - 4.69}{80.0 - 0.0}$ = 0.0205 [$\Omega\,°C^{-1}$] Min gradient = $\frac{6.17 - 4.86}{80.0 - 0.0}$ = 0.0164 [$\Omega\,°C^{-1}$] Marking tips: First check: The value of m_{max} should be ~ 0.021 [$\Omega\,°C^{-1}$] and the value of m_{min} should be about 0.016 [$\Omega\,°C^{-1}$]. Candidates who have drawn lines which do not take full advantage of the error bars may get <0.020 and >0.017 respectively. This is penalised in (c), so apply **ecf**. Candidates who have drawn 'tram lines' will have two nearly identical values of ~ 0.018. Again **ecf** should be applied.	3
	(ii)	Mean gradient correct (1) [Exemplar value ~ 0.0184[5] [$\Omega\,°C^{-1}$] but apply **ecf** from *(b)* and *(d)*(i)]. No unit penalty. Percentage uncertainty correct (1) [Exemplar value ~ 11%. Allow 1 or 2 sig figs. Apply **ecf** from *(b)* and (*d*)(i)].	2
(e)	(i)	Mean value correct [Exemplar value 4.78 [Ω]]. (1) Percentage uncertainty correct [Exemplar value ~2% - allow 1 or 2 sig figs]. (1) Allow **ecf**. Intercept = Resistance (of copper) at 0 °C. (1)	3
	(ii)	$\alpha = \frac{\text{gradient}}{R_0}$ or $\alpha = \frac{\text{gradient}}{\text{intercept}}$ stated or implied by calc. (1) Correct calculation, i.e. $\alpha = \frac{\text{answer to }(d)(ii)}{\text{answer to }(e)(i)}$ (1) $\alpha = 3.9 \times 10^{-3}$ [Accept answer in range 3.8 to 4.0 × 10^{-3}]. (1) Note: This mark is for accuracy. Do not apply **ecf**. No sig figs penalty. Unit given as $°C^{-1}$ (or K^{-1}). (1) N.B. If data points selected from the graph or table (1), calculation of α (1), correct unit (1) i.e. maximum of 3 marks awarded.	4
	(iii)	Total % uncertainty = % in *(d)*(ii) + % in *(e)*(i). (1) [Exemplar value ~ 13%. Apply **ecf**] Absolute uncertainty correct and given to 1 or 2 sig figs. (1) [Exemplar value ~ 0.5 × 10^{-3}] Temperature coefficient of resistance written correctly with its uncertainty, ignore unit, the value given to number of sig figs consistent with uncertainty [e.g. 0.0039 ± 0.0005 $°C^{-1}$; (3.9 ± 0.5) × $10^{-3}\,°C^{-1}$. (1) Award the mark if α and absolute uncertainty calculated correctly but written separately.	3
		Question total	**25**

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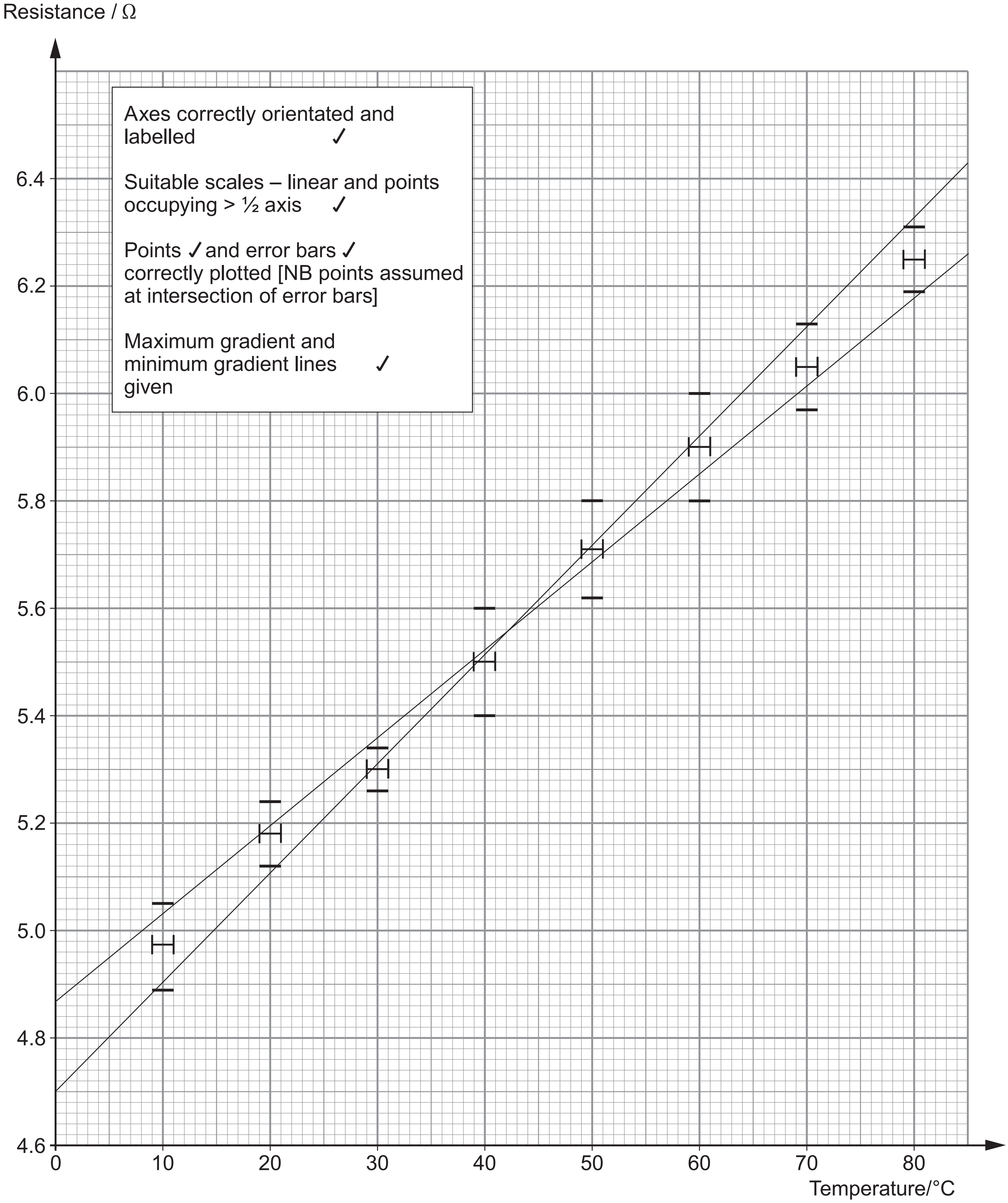
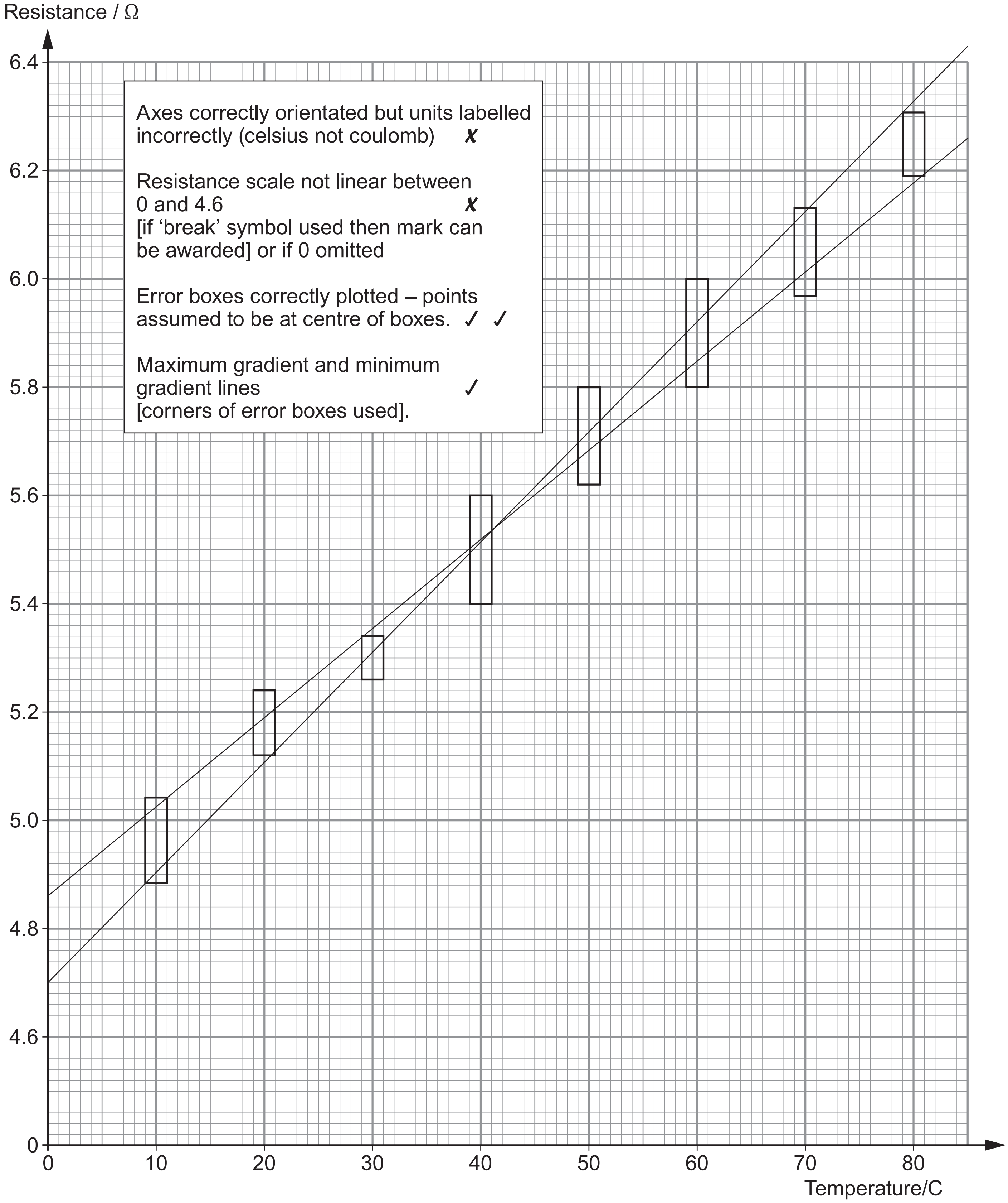
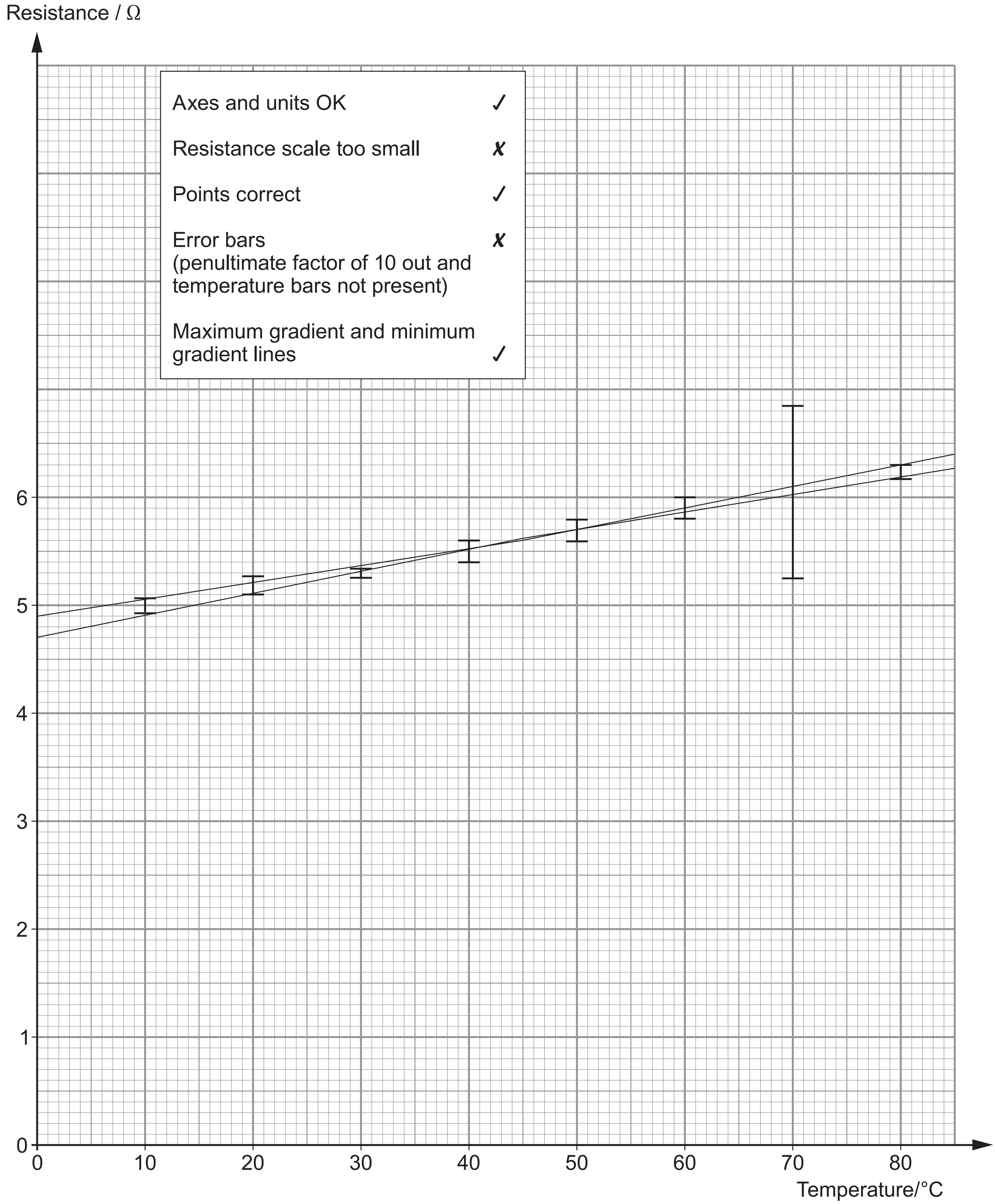
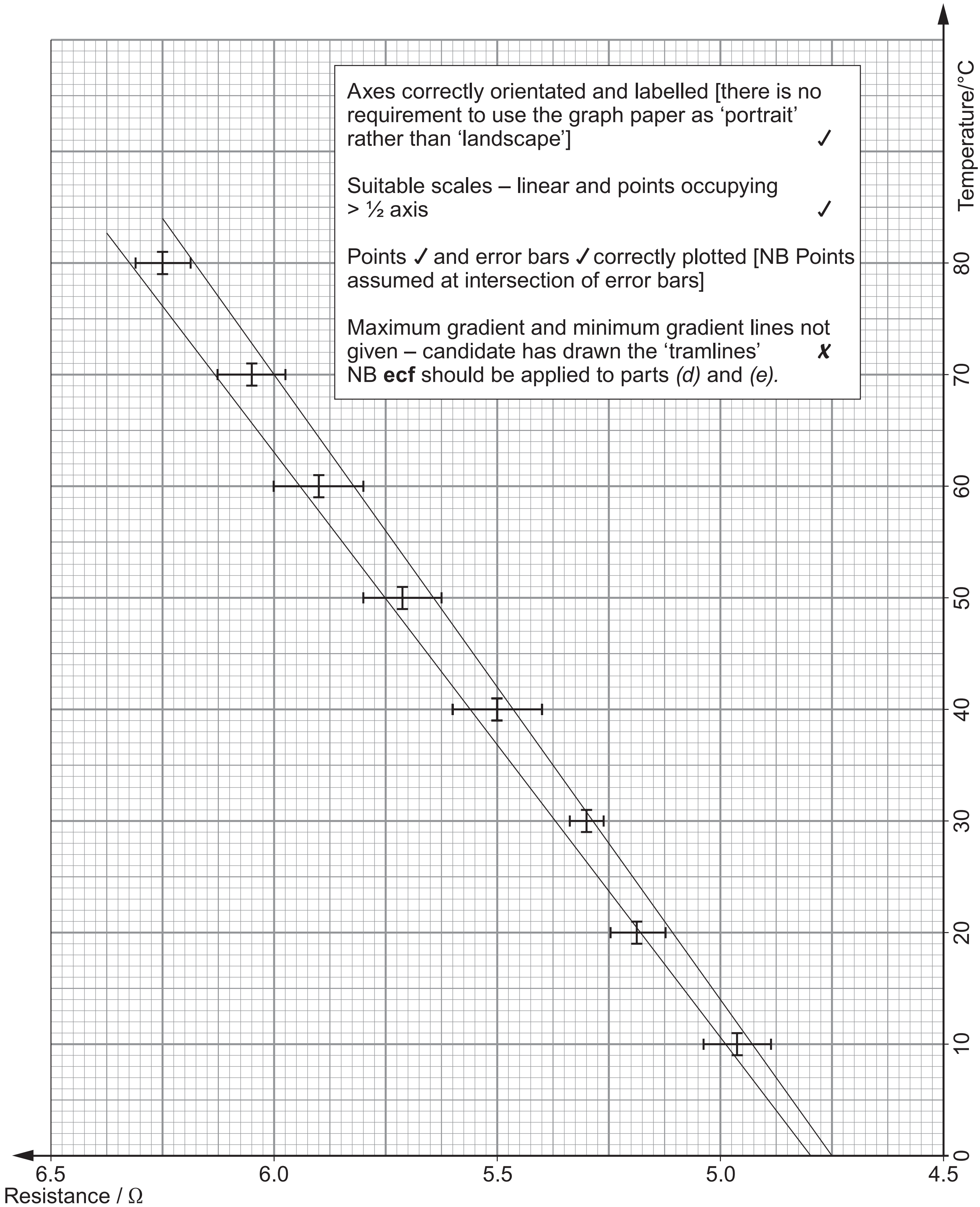

Resistance / Ω
Axes correctly orientated and labelled ✓
Suitable scales – linear and points occupying > ½ axis ✓
Points ✓ and error bars ✓ correctly plotted [NB points assumed at intersection of error bars]
Maximum gradient and minimum gradient lines given ✓
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
0
10
20
30
40
50
60
70
80
Temperature/°C



Resistance / Ω
6.4
6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
0
0
10
20
30
40
50
60
70
80
Temperature/C
Axes correctly orientated but units labelled incorrectly (celsius not coulomb) ✗
Resistance scale not linear between 0 and 4.6 ✗
[if 'break' symbol used then mark can be awarded] or if 0 omitted
Error boxes correctly plotted – points assumed to be at centre of boxes. ✓ ✓
Maximum gradient and minimum gradient lines ✓
[corners of error boxes used].


Resistance / Ω
Axes and units OK ✓
Resistance scale too small ✗
Points correct ✓
Error bars ✗
(penultimate factor of 10 out and temperature bars not present)
Maximum gradient and minimum gradient lines ✓
6
5
4
3
2
1
0
0
10
20
30
40
50
60
70
80
Temperature/°C

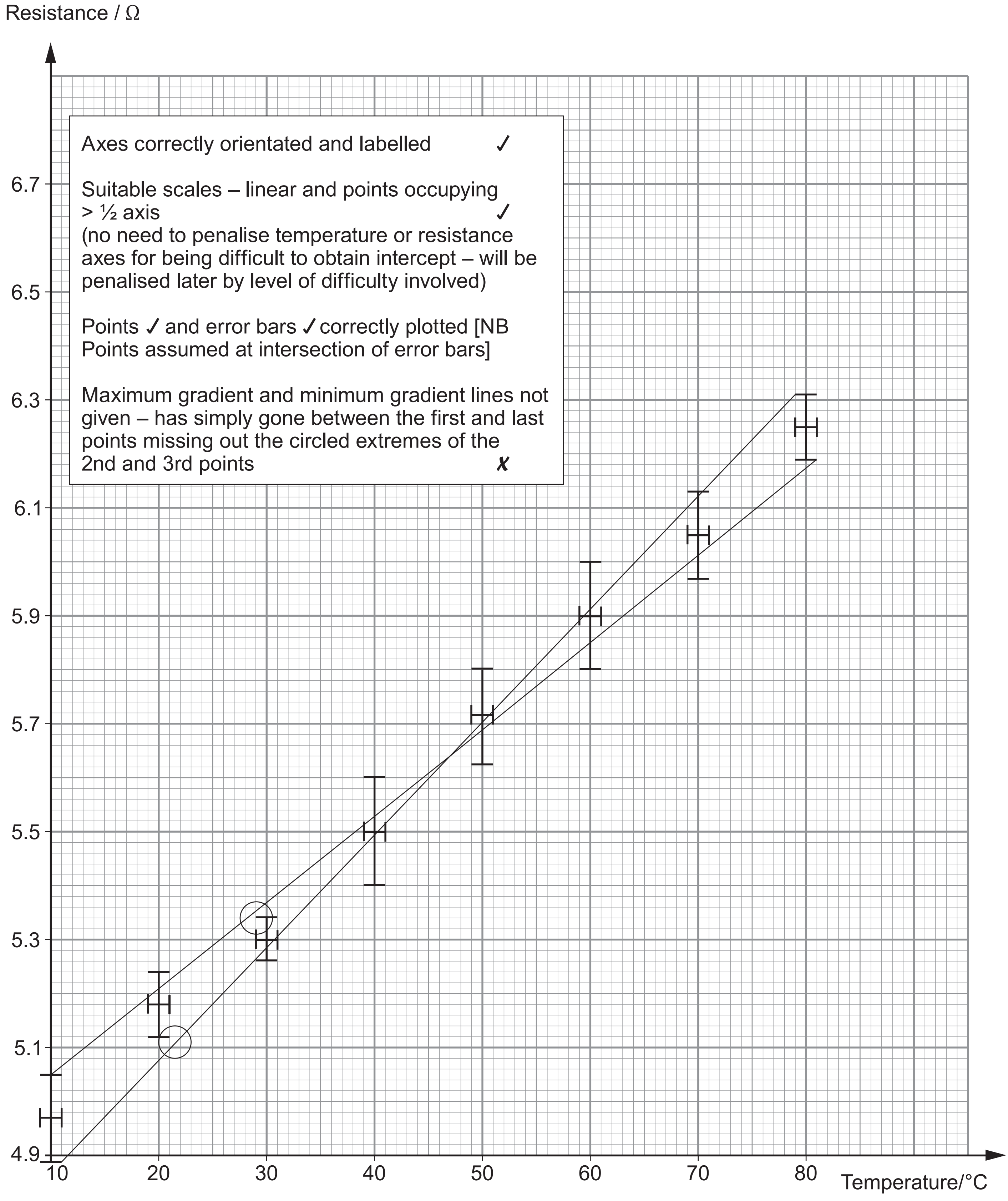


Axes correctly orientated and labelled [there is no requirement to use the graph paper as 'portrait' rather than 'landscape'] ✓

Suitable scales – linear and points occupying > ½ axis ✓

Points ✓ and error bars ✓ correctly plotted [NB Points assumed at intersection of error bars]

Maximum gradient and minimum gradient lines not given – candidate has drawn the 'tramlines' ✗
NB **ecf** should be applied to parts *(d)* and *(e)*.



Resistance / Ω
Axes correctly orientated and labelled ✓
Suitable scales – linear and points occupying > ½ axis ✓
(no need to penalise temperature or resistance axes for being difficult to obtain intercept – will be penalised later by level of difficulty involved)
Points ✓ and error bars ✓ correctly plotted [NB Points assumed at intersection of error bars]
Maximum gradient and minimum gradient lines not given – has simply gone between the first and last points missing out the circled extremes of the 2nd and 3rd points ✗
6.7
6.5
6.3
6.1
5.9
5.7
5.5
5.3
5.1
4.9
10
20
30
40
50
60
70
80
Temperature/°C