GCE MARKING SCHEME

PHYSICS
AS/Advanced

SUMMER 2014

INTRODUCTION

The marking schemes which follow were those used by WJEC for the Summer 2014 examination in GCE PHYSICS. They were finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conferences were held shortly after the papers were taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conferences was to ensure that the marking schemes were interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conferences, teachers may have different views on certain matters of detail or interpretation.

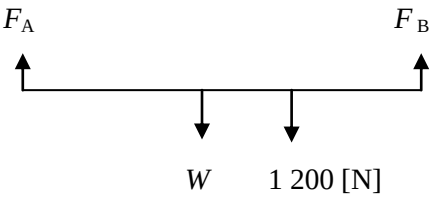
WJEC regrets that it cannot enter into any discussion or correspondence about these marking schemes.

Question			Marking details	Marks Available
1	*(a)*	(i)	Energy cannot be created or destroyed; it can only change from one form to another. Don't accept can only be conserved.	[1]
		(ii)	$E_p \rightarrow E_k$ (1) can be implied Some energy lost as heat **or** due to air resistance **or** due to friction with air - general statement (1) Air molecules gain E_k and/or molecules of object gain E_k - **specific** statement (1)	[3]
	(b)	(i)	mgh calculated correctly = 376.7 [J] (1) accept g as 9.8 or 9.81 but not 10 $\frac{1}{2}mv^2$ calculated correctly = 288 [J] (1) $E_p - E_k$ = 88.7 [J] [**ecf** from calculated values of E_p and/or E_k] (1)	[3]
		(ii)	Correct substitution into $W = Fd$ i.e. 88.7 (**ecf**) = $F \times 4.0$ (1) F = 22[.2 N] (1) If either E_p or E_k substituted in for W then award 1 mark only **Alternative Solution:** Force down slope = $16 \times 9.81 \times \frac{2.4}{4}$ [$F = mg\sin\theta$] = 94.2 [N] Resultant Force $\Sigma F = 16 \times \left(\frac{6^2}{8}\right)$ = 72 [N] Mean Frictional Force = 94.2 – 72 = 22[.2 N] Award 1 mark for **either** force values correct (or both) Award 2 marks for correct solution	[2]
			Question 1 total	**[9]**
2	*(a)*	(i)	Force α extension [provided elastic limit is not exceeded] Accept F α x but x must be defined	[1]
		(ii)	4.0 [cm]	[1]
	(b)		F (from graph) = 0.6 [N] (1) Correct application of $a = \frac{\sum F}{m}$ i.e $\frac{0.6}{0.4} = 1.5\,\text{m s}^{-2}$ (1) **UNIT mark** (**ecf** on F)	[2]
	(c)	(i)	substitution into ½ Fx (**or** area under graph **or** ½ kx^2) (1) **ecf** on F $E_{\text{spring}} = 3.6 \times 10^{-2}$ [J] (1)	[2]
		(ii)	E_{spring} = 0 [J] (1) ΣF = 0 **or** acceleration = 0 so extension = 0 (1)	[2]
	(d)		New extension = ½ × original (1) Force in each spring = ½ × original **or** spring constant of system = 2 × original **or** energy in each spring = ¼ × original (1) Total energy (in both springs) = ½ × original (1) Accept algebraic equivalents	[3]
			Question 2 total	**[11]**

Question			Marking details	Marks Available
3	*(a)*	(i)	$J\ s^{-1}$	[3×1]
		(ii)	$V\ A^{-1}$	
		(iii)	$A\ s$	
	(b)	(i)	$t = 2 \times 3\,600$ or $7\,200$ s (1) $Q = 0.15 \times 7\,200 = 1\,080$ [C] (1)	[2]
		(ii)	$\frac{6480}{1080} = 6$ [V] (**ecf** on *Q*)	[1]
		(iii)	$\frac{5832}{1080} = 5.4$ [V] (**ecf** on *Q*)	[1]
		(iv)	6 - 5.4 = 0.6 [V] (1) (**ecf** from *(b)*(ii) & (iii)) $\frac{0.6}{0.15} = 4$ [Ω] (1) (**ecf** on 0.6 [V]) **Or** Correct substitution into $V=E - Ir$ (i.e. $5.4 = 6.0 - 0.15r$) (1) $r = 4$ [Ω] (1) (**ecf** from *(b)*(ii) & (iii)) **Alternative Solution:** $\frac{(6480-5832)}{7200} = 0.09\ J\ s^{-1}$ (Lost energy in cell per second) (1) $I^2r = 0.09$ and $r = 4$ [Ω] (1)	[2]
			Question 3 Total	**[9]**

Question			Marking details	Marks Available
4	*(a)*		Electrical energy (**or** work done) transferred [to other forms passing] between two points (1) per coulomb of charge (1) Definition of 1 V award 1 mark only	[2]
	(b)	(i)	$V_{supply} = V_1+V_2+V_3$	[1]
		(ii)	Energy	[1]
	(c)	(i)	$R_1+12 = \frac{9}{0.5}$ (1) Clear manipulation seen to show $R_1=6\,[\Omega]$ (1)	[2]
		(ii) (I)	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ to show effective parallel combination = $6\,\Omega$ (1) this can be implied V across upper $6\,\Omega$ resistor shown = $4.5\,[\text{V}]$ (**ecf** on parallel combination) (1)	[2]
		(II)	Total resistance = $12\,\Omega$ (1) $I = \frac{9.0}{12} = 0.75\,[\text{A}]$ (1) (accept $\frac{4.5}{6} = 0.75$ [A])	[2]
		(III)	$1.2 = \frac{9}{(6+R_{parallel})}$ (1) $R_{\text{parallel}} = 1.5\,[\Omega]$ (1) $n \times (\frac{1}{12}) = \frac{1}{1.5}$ (1) **ecf** on $1.5\,[\Omega]$ $n = 8$ (1) Full marks for correct answer based on trial and error **Alternative solution:** $\frac{9}{1.2} = 7.5$ [Ω] (1) 7.5 – 6 = 1.5 [Ω] (1) $\frac{12}{n} = 1.5$ [Ω] (1) $n = 8$ (1)	[4]
			Question 4 Total	**[14]**

Question			Marking details	Marks Available
5	*(a)*	(i)	Ruler and wire shown and labelled (1) Moving pointer **or** jockey **or** crocodile clip indicated (1) **Either**: Correctly positioned ohmmeter with no power supply; **or** correctly positioned voltmeter and ammeter with power supply (1) [No labelling required for either method].	[3]
		(ii)	Diagonal line through origin	[1]
		(iii)	CSA from <u>diameter of wire</u> (1) Gradient from graph = (R/l) **or** (ρ/A) **Or** stated take a pair of R and l values from the graph (1) ρ = gradient × CSA **or** use of $\rho = RA/l$ (1)	[3]
	(b)	(i)	$R = \frac{144}{32} = 4.5\,[\Omega]$ (1) Correct substitution into $R = \rho l/A$ (1) $l = 0.375$ [m] (1) (**ecf** on R)	[3]
		(ii)	$I = 2.7$ [A] (from V/R **or** P/V etc) (1) (**ecf** on I) Correct substitution into $I = nAve$ (1) $v = 1.24 \times 10^{-2}$ [m s^{-1}] (1) accept 0.01 m s^{-1}	[3]
			Question 5 Total	**[13]**

Question			Marking details	Marks Available
6	*(a)*	(i)	Acceleration defined as rate of change of velocity [**or** equivalent] **or** $a = \frac{(v-u)}{t}$ (1) Clear manipulation to show that $v=u+at$ (1)	[2]
		(ii)	$v=u+at$ substituted into $x = (u+v)t/2$ (1) Clear manipulation shown (1)	[2]
	(b)	(i)	A (1) Horizontal velocity (= 65 $m\,s^{-1}$) constant **or** same speed as plane **or** sack lands directly underneath plane (1) Vertical velocity increases **or** there is a vertical acceleration (1)	[3]
		(ii) (I)	Substitution into $v^2=u^2+2ax$ **and** $u = 0$ shown (1) x calculated = 45.9 [m] (1)	[2]
		(II)	Correct substitution into $v = at$ **or** $x=1/2at^2$ ***or*** $x=\frac{(u+v)t}{2}$ (1) t=3.1 [s] (1)	[2]
		(iii)	$v_R^2= (65^2 + 30^2)$ (correct substitution into Pythagoras) (1) $v_R = 71.6$ [$m\,s^{-1}$] (1) Valid angle calculated and shown **or** described e.g. $\theta = 24.8°$ below horizontal (1)	[3]
			Question 6 Total	**[14]**
7	*(a)*		Replace *mass* with *force* (1) Don't accept weight Introduce *perpendicular distance to pivot* (1)	[2]
	(b)		$(2 \times 700) - 1\,200$ (1) Weight of beam = 200 [N] (1) **Alternative solution:** Moment about A or B e.g. $(700 \times 5) = (1\,200 + W) \times 2.5$	[2]
	(c)	(i)	 Upward forces as shown and indicated (1) Downward forces as shown and indicated (1) N.B. 1 200 [N] force can be indicated anywhere between W and F_B	[2]
		(ii)	Taking moments about A: $F_B \times 5.0$ (1) $(1\,200 \times 3.5) + (200 \times 2.5)$ (1) (**ecf** on 200) F_B = 940 [N] (1)	[3]
		(iii)	1 400 – 940 = 460 [N] (**ecf** from (*b*) and/or (*c*)(ii)) Accept answer based on moments calculated about B.	[1]
			Question 7 Total	**[10]**

Question			Marking details	Marks Available
1	*(a)*	(i)	Attempt at sinusoid, right way up, passing within 1 mm of all dots	1
		(ii)	P and Q are in phase (1) Amplitude of P > amplitude of Q (1)	2
		(iii)	Q and R are in antiphase / exactly out of phase (1) Amplitude of Q = amplitude of R (1)	2
		(iv)	$\frac{\lambda}{2}$ = 0.20 [m] **or** λ = 0.40 [m] **or** by implication (1) v = 96 m s^{-1} **UNIT** **ecf** (1)	2
	(b)		$\frac{\lambda}{2}$ = 0.15 [m] (**or** λ = 0.30 [m]) **or** v = 96 [m s^{-1}] **ecf** from *(a)*(iv) **or** $f = \left(\frac{4}{3}\right)$ 240 [Hz] **or** by implication (1) f = 320 [Hz] but not by cancellation of errors, **ecf** on v from *(a)*(iv) (1)	2
			Question 1 total	**[9]**
2	*(a)*	(i)	$S_2Q = \sqrt{(350^2 + 120^2)}$ [mm] **or** equivalent (1) Therefore $S_2Q - S_1Q$ = (370 – 350) [mm] (1)	2
		(ii)	For any dot, path difference = $n\lambda$, **or** for P, path difference = 0 **or** any other remark relevant to the conclusion that ... (1) λ = 10 [mm] (1)	2
		(iii)	$\lambda = \left(\frac{120\text{x}30}{350}\right)$ (1) λ = 10 mm **or** 10.3 mm **UNIT** (1)	2
	(b)		With sensor in front of source **either** rotate sensor [at least through 90°] **or** interpose array of metal rods /metal grille and rotate [at least through 90°] (1) Don't accept metal grid Signal strength changes (1) Accept in words or in diagram	2
			Question 2 total	**[8]**

Question			Marking details	Marks Available
3	*(a)*		[Flat, opaque] screen / sheet/ plate / material with slits / gaps (1) Slits are parallel / vertical **or** equally spaced **or** closely spaced **or** many / multiple (1)	2
	(b)	(i)	$\frac{1}{400000}$ = [2.5×10^{-6} m]	1
		(ii)	$2\lambda = 2.5 \times 10^{-6}$ sin 25.2° even with the 2 missing or mishandled (1) Correct placing of the 2 (1) $\lambda = 532 \times 10^{-9}$ [m] **ecf** on *d* only (1)	3
		(iii)	$3 \times 532 = 2\,500 \sin\theta$ or equivalent **ecf** on λ (1) $\theta = 39.7°$ or 40° **ecf** on λ (1)	2
		(iv)	Young's slits much further apart than slits in grating Don't accept slits much narrower **or** gaps are much smaller	1
			Question 3 Total	**[9]**
4	*(a)*	(i)	medium 1: 2.0×10^8 [m s^{-1}] **and** medium 2: 2.5×10^8 [m s^{-1}]	1
		(ii)	Correct use of sin 30° seen clearly (1) Rest of argument, including use of $t = \frac{d}{v}$ [**ecf** on *v* and on value of sin 30°, if failure to reach the stated time is noted]. (1)	2
		(iii)	BD = 2.5×10^8 **ecf** $\times$ 2.5×10^{-11} [m] [= 6.25 mm] **or** by implication (1) θ_2= 38.7° (or 39°) **ecf** on $v = 2.5 \times 10^8$ [m s^{-1}] (1)	2
		(iv)	1.50 sin 30° = 1.20 sin θ_2 (1) Therefore θ_2= 38.7° (or 39°) **no ecf** (1)	2
	(b)	(i)	Use of $v = 2.0 \times 10^8$ [m s^{-1}] (1) $t = \frac{1600}{2.0 \times 10^8}$ [s] **ecf** on *v* (1)	2
		(ii)	Critical angle = 76° **or** by implication (1) n_{clad} [× sin 90°] = 1.500 sin 76° **ecf** on 76° **or** by implication (1) n_{clad} = 1.455 **or** 1.46 **do not accept** 1.45 **no ecf** (1)	3
		(iii)	$\frac{AC}{AB}$ = cos 14° **or** equivalent **or** by implication (1) Δt = 0.24 μs **ecf** on *v* (1)	2
			Question 4 Total	**[14]**

Question			Marking details	Marks Available
5	*(a)*		[Minimum] energy needed to release [**or** eject] electron from magnesium [**or** metal **or** surface **or** solid **not** atom]	1
	(b)		$E_{k\,max} = 6.63 \times 10^{-34} \times 1.16 \times 10^{15}$ [J] – 5.9×10^{-19} [J] (1) $E_{k\,max} = 1.79 \times 10^{-19}$[J] (1)	2
	(c)		Photon energy < work function (1) don't accept photon energy in symbols. Accept not enough energy to liberate an electron. Don't accept $E_{k\,max}$ can't be negative. $E_{phot} = 5.4 \times 10^{-19}$[J] **accept** $f_{thresh} = 8.9 \times 10^{14}$ [Hz] (1) If negative energy award 1 mark only	2
	(d)	(i)	Planck constant. **Accept** Planck's constant **or** *h*.	1
		(ii)	[–] work function. **Accept** [–] ϕ.	1
		(iii)	f_0 **or** minimum frequency to eject electron **or** threshold frequency	1
			Question 5 Total	**[8]**
6	*(a)*	(i)	**Any 2 × (1) from:** • Monochromatic **or** same frequency **or** same wavelength • Wavefronts continuous **or** light in phase across width of beam • Photons in phase	2
		(ii)	Use of $E = hf$ **and** $f = \frac{c}{\lambda}$ **or** $E = \frac{hc}{\lambda}$ (1) 1.87×10^{-19} [J] (1)	2
		(iii)	1.3×10^{20} [s^{-1}] **ecf**	1
		(iv)	Downward arrow from U to L (1) 2.29×10^{-19} J (or 2.3×10^{-19} J) (1) **ecf**	2
	(b)		[Passing] photon stimulates electron to drop from U to L (1) Emitting another photon (1) **Any 2 × (1) from:** • Process may happen repeatedly (or equivalent) as photons traverse cavity • Population inversion [between U and L] needed for stimulated emission to predominate over absorption • Pumping to P and drop to U brings about inversion • Level L self-emptying so less pumping needed **or** population inversion easier to accomplish • In phase with **or** travelling in the same direction as **or** polarised in the same direction as **or** identical to passing photon • Stimulated photon must have an energy of 1.87×10^{-19} J or equivalent	4
			Question 6 Total	**[11]**

Question			Marking details	Marks Available
7	*(a)*	(i)	$\lambda_{peak} = \frac{2.90\text{x}10^{-3}}{9900}$ [m] **or equivalent** (1) $\lambda_{peak} = 293 \times 10^{-9}$ [m] (1)	2
		(ii)	Peak between 280 and 300 nm (1) Curve goes through origin [with zero gradient at origin] and is consistent with approaching zero at very long wavelengths (1)	2
		(iii)	Blue accept white **or** violet **or** purple	1
	(b)		$A = \frac{L}{\sigma T^4}$ with A as subject, with symbols **or** data **or** 1.84×10^{19} m^2 (1) Attempt to use $A = 4\pi r^2$ and $d = 2r$ **or** $A = \pi I^2$ (1) $d = 2.4 \times 10^9$ m **ecf** on slips of 2^n or 10^n if already penalised (1)	3
	(c)	(i)	Absorption **accept** excitation **Don't accept** pumping	1
		(ii)	Dark / black lines crossing **or** missing wavelengths [continuous] spectrum **or** coloured background	1
		(iii)	B almost absent **and** any reference to populations of levels (1) First excited state not populated [so no transitions start here] **or** all electrons in ground state (1)	2
			Question 7 Total	**[12]**
8	*(a)*	(i)	$\text{uud} + \text{uud} \rightarrow \text{uud} + \text{udd}$ (1) $+\text{u}\bar{\text{d}}$ (1)	2
		(ii)	1 + 1 > 1 + 1 + 0 (all numbers must be shown) **or** equivalent	1
		(iii)	Strong because no [photons (gammas) or] neutrinos **or** no flavour changes	1
		(iv)	Charge **or** momentum **or** energy **or** strangeness Accept up quark number **or** down quark number	1
	(b)	(i)	0 + 0 > 0 + (–1) + 1 (all numbers must be shown)	1
		(ii)	Weak interaction **accept** fusion (1) Takes place in the Sun [accept stars] (1) Part of the process whereby we get sunlight **or** energy **or** equivalent (1)	3
			Question 8 Total	**[9]**

PH3

TEST 1 – Mark Scheme

SECTION A

A1.

(a) Appropriate measurements taken to ± 1 mm. *(1)*
Volume calculated correctly with correct unit. Ignore sig figs. *(1)* [2]

(b) Using correct instrument resolution for uncertainty (± 1 mm) Accept (± ½ mm). *(1)*
All percentage uncertainties calculated correctly. **ecf** on resolution *(1)*
Percentage uncertainties added to give final value. *(1)* No sig fig penalty. [3]
(Allow **ecf** on incorrect % uncertainty; need to add 3 values)

(c) (i) Absolute uncertainty calculated correctly. No sig fig or unit penalty. **ecf** [1]

(ii) Value of the absolute uncertainty to 1 or 2 sig figs and
volume to the same precision **and unit quoted**
e.g. 152 ± 11 cm^3 or 150 000 + 10 000 mm^3. **ecf** [1]

(d) Measuring instrument with a lower instrument resolution (accept reference to precision but not accuracy) OR use of calipers or micrometer [1]

Total [8]

A2.

(a) Unit of extension in the table (accept mm or cm or m). *(1)*
Extension measured consistently to the nearest mm. *(1)*
Mean value of k calculated correctly. *(1)* No sig fig penalty. Answer must be seen in *(a)*
Unit of k correct. *(1)* (Accept: $N\,m^{-1}$ or $N\,mm^{-1}$ or $kg\,s^{-2}$ or $kg\,m\,s^{-2}\,mm^{-1}$.) [4]

(b) Absolute uncertainty calculated correctly. *(1)* No sig fig or unit penalty.
Percentage uncertainty calculated correctly. **ecf** *(1)* No sig fig penalty. [2]
N.B. If all values for k are the same then candidate needs to state that the uncertainty is 0 *(1)* and the % uncertainty is 0. *(1)*
Or if candidate calculates % uncertainty in extension *(1)* % uncertainty in k = % uncertainty in extension. *(1)*

(c) Correct rearrangement of equation $m = \frac{kx}{g}$ or implied. *(1)*
Value of m = 0.120 kg. **Unit required**. *(1)* (Accept 0.11–0.13)
Accept answer in grammes. [2]

Total [8]

A3.

(a) Value of correct time or velocity repeated and mean taken. *(1)*
Velocity calculated correctly including unit ($m\,s^{-1}$). **ecf** *(1)* No sig fig penalty. [2]

(b) (i) All units correct. *(1)*
Columns for mean time and mean velocity correct. *(1)*
Values for v^2 correct. **ecf** *(1)*
Consistent use of 2 dps in each column of data. *(1)* [4]

(ii) Valid conclusion made with some reference to the data. *(1)*

Ratio $\frac{n}{v^2}$ or $\frac{v^2}{n}$ calculated for all 3 rows. *(1)*

[2]

Total [8]

SECTION B

B4

(a) (i) Circuit diagram drawn with correct symbols (ignore positions of voltmeter and ammeter for this mark). *(1)*
Voltmeter and ammeter correctly positioned. *(1)* [2]

(ii) Change length and measure V and I. *(1)*
Reference to $R = \frac{V}{I}$. *(1)*
Suitable intervals stated allow intervals up to a maximum of 0.2 m. *(1)* [3]
None of the above can be awarded from the table.

(b) Clear headings (length or l / current or I / voltage or pd or V / resistance or R) and correct units on all columns. *(1)*
Values of voltage; current; given in sequential values of length. *(1)*
Resistance calculated correctly. *(1)*
All I and V values given to 2 dp *(1)* [4]

(c) Graph of resistance against length plotted with axes labelled and correct units given on both axes. *(1)* **ecf from table**
Suitable scale chosen (don't allow multiples of 3) so that all data points occupy at least half the graph paper. *(1)*
All points plotted correctly to within ± ½ small square division. *(1)*
1 good line of best fit consistent with the data. *(1)*
2 good distinct lines of best fit drawn showing difference in gradient. *(1)* [5]

(d) Distance correctly read from the graph. (allow ± ½ small square division) *(1)*
Unit and value given to the nearest cm or consistent with the scale used on the graph.
Apply **ecf** if distance read incorrectly. *(1)* [2]

(e) (i) Large triangle used *(1)* (should be close to the extremities of the line of best fit for wire starting at X) [or 2 equivalent suitable points clearly indicated on the graph].
Correct values used for gradient calculation. *(1)*
Gradient calculated correctly. **ecf**. No unit penalty.*(1)* If wire starting at Y do not award this mark. [3]

(ii) Measuring the diameter of the wire starting at X. *(1)* No unit or sig fig penalty. Accept in the range 0.28-0.33
Correct calculation of the cross-sectional area. *(1)* No unit or sig fig penalty.
Realising that gradient of the graph = $\frac{\rho}{A}$ (can be applied anywhere in the answer) or using data values from the line of the graph. *(1)*
Calculating a value for resistivity in Ω m. *(1)* **ecf** for gradient and area.
No unit or sig fig penalty. If data taken from the table and it is not on the graph line award 1 mark only.
Correct conclusion consistent with their resistivity value. *(1)*
[5]
(Candidates need to calculate a value for resistivity before conclusion mark can be awarded.)

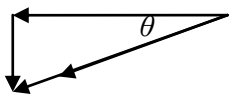
Total [24]

TEST 2 – Mark Scheme as TEST 1

Except:

A2*(c)* 2nd mark: Value of m = 0.160 kg. Unit required. *(1)* (Accept 0.15–0.17)

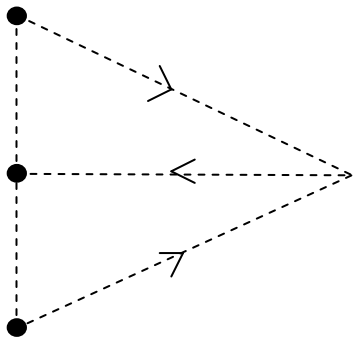
A3 *(b)*(ii) 2nd mark: Ratio $\frac{n}{v^2}$ or $\frac{v^2}{n}$ calculated for at least 3 rows of data or 2 sets of data. *(1)*

Question			Marking details	Marks Available
1	*(a)*		Reasonable attempt at conservation of momentum (1) e.g. $330\,000m = \pm 10\,000m + 6.6 \times 10^{-27} \times v_1$ conservation of momentum applied correctly and values substituted (1) e.g. $330\,000 \times 3.4 \times 10^{-25} = -10\,000 \times 3.3 \times 10^{-25} + 6.6 \times 10^{-27} \times v_1$ correct answer = 1.75×10^{7} [m s^{-1}] (**no ecf**) (1)	3
	(b)	(i)	Any valid answer e.g. impulse (**or** force **or** acceleration **or** change in momentum) is vertical, gamma has no momentum in horizontal direction, perpendicular directions are independent etc. Accept: no horizontal force	1
		(ii)	Attempt at using $p = \frac{h}{\lambda}$ (1) $E = hf$ **and** $c = f\lambda$ quoted (**or** equivalent $E = \frac{hc}{\lambda}$) (1) N.B. $p = \frac{E}{c}$ gains 2 marks Correct momentum = 6.33×10^{-22} (1) Answer = $= \frac{6.33\times10^{-22}}{3.3\times10^{-25}}$ [1 920 m s^{-1}] (1)	4
		(iii)	Method i.e. $\sqrt{10000^2 + 2000^2}$ (1) Answer = $10\,200$ [m s^{-1}] **ecf** on *v* from *(b)*(ii) (1) Method and correct **indication of angle** e.g. $\tan^{-1}\left(\frac{2000}{10000}\right)$ (1)  Answer $= 11.5°$ **or** 0.2 [rad] (or 90-11.5 for other angle if indicated etc.) (1)	4
			Question 1 Total	**[12]**

Question			Marking details	Marks Available
2	*(a)*	(i)	(Number of moles) n = 4.73 (1)	3
			Mass = 4 × 4.73 **or** 0.004 × 4.73 (**or** implied) (1)	
			Density = 0.004 × 4.73 / 0.113 [= 0.167] (1)	
		(ii)	Either $p = {}^{1}/_{3}\,\rho\overline{c^2}$ used **or** equivalent e.g. ${}^{3}/_{2}\,nRT = {}^{1}/_{2}\,M\overline{c^2}$ (1)	2
			1 350 [m s^{-1}] (1)	
	(b)		Density = 0.004 × 4.73 / 0.212 **or** $T = \frac{45000\times0.212}{4.73\times8.31}$ **ecf** (1)	3
			$p = {}^{1}/_{3}\,\rho\overline{c^2}$ used **or** ${}^{3}/_{2}\,nRT = {}^{1}/_{2}\,M\overline{c^2}$ used **or** equivalent (1)	
			Answer = 1 230 [m s^{-1}] (1)	
			Question 2 Total	**[8]**
3	*(a)*		Substitution into $v = \sqrt{\frac{GM}{r}}$ (1)	2
			Answer = 158 000 [m s^{-1}] (1)	
	(b)		Measured velocity is greater (1)	3
			Which implies that the mass is greater (1)	
			Suggests the existence of dark matter (1)	
			Question 3 Total	**[5]**

Question			Marking details	Marks Available
4	*(a)*		Mass substituted into $T = 2\pi\sqrt{\frac{m}{k}}$ (1) $T = \frac{1}{f}$ used **or** implied (1) Answer = 152 N m^{-1} **UNIT mark** (1)	3
	(b)		3.47 × 2π [= 21.803]	1
	(c)	(i)	$v = \omega A$ [= 1.853] **or** max PE = max KE (1) KE = $^1/_2\, mv^2$ used **or** = ½ kx^2 (1) Answer = 0.55 [J] (1)	3
		(ii)	Acceleration = $\omega^2 A$ **or** $F = kA$ Accept $F = kA - mg$ (1) Answer = 12.9 [N] (1)	2
	(d)		Substitution of values e.g. $-1.4 = 8.5\sin(21.8 \times 0.1 + \varepsilon)$ (1) $\sin^{-1}\left(^{-1.4}/_{8.5}\right) = -0.165$ (1) $\varepsilon = -2.35$ **or** equivalent in degree (-135^o) **or** other quadrant (-5.16) **ecf** on minus sign (1)	3
			Question 4 total	**[12]**

Question			Marking details	Marks Available
5	*(a)*	(i)	Force per unit mass (this minimalist answer is acceptable unless some contradiction)	1
		(ii)	Work done per unit mass <u>from infinity</u> (this minimalist answer is acceptable unless some contradiction)	1
	(b)	(i)	$F = \frac{GMm}{r^2}$ used (1) Answer = 22.8 [N] (1)	2
		(ii)	$PE = [-]\frac{GMm}{r}$ used **or** equivalent (1) Answer = - 13.7 M[J] (1)	2
	(c)		$PE = [-]\frac{GMm}{r}$ used **or** equivalent (1) Answer = - 61.8 M[J] (**ecf** on – sign) (1)	2
	(d)		Difference in PE attempted (1) Correct answer = 48.1 M[J] (*(b)*(ii) – *(c)*) **ecf** (1) Answer must be consistent with their signs	2
			Question 5 Total	**[10]**

Question			Marking details	Marks Available
6	*(a)*		All arrows correct ✓✓ Directions in line with dotted lines but some (or all) directions inverted ✓ 	2
	(b)		$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ used (1) Answer = 1 500 V m^{-1} **or** N C^{-1} **or** equivalent **UNIT mark** (1)	2
	(c)		Field of 13 μC ×2 **and** ×12/13 (1) Answer = 222 [V m^{-1}] (1) To the left **or** implied clearly in the calculation (1)	3
	(d)		$V = \frac{Q}{4\pi\varepsilon_0 r}$ used for 3 charges with r = 12 or 13 (1) $V = \frac{1}{4\pi\varepsilon_0}\left(2\frac{13}{13} - \frac{24}{12}\right)$ as shown **or** equivalent (cm perfectly valid) (1)	2
	(e)		**Any 3 (×1) from:** • initial **total** energy is zero / initial and final PE is zero • final **total** energy is zero / initial and final KE is zero • initial force is to the right (has to be linked to the field and the negative charge) • later the force is to the left (but not a resistive force)	3
			Question 6 Total	**[12]**

Question			Marking details	Marks Available
7	*(a)*		$T = 2\pi\sqrt{\dfrac{(3\times10^{10})^3}{6.67\times10^{-11}\times(7\times10^{29}+\mathbf{4}\times\mathbf{10^{28}})}}$ (1) Answer = 4.65×10^{6} [s] (1) (4.78×10^{6} s scores 1/2 marks)	2
	(b)		$r_1 = \frac{M_1}{M_1+M_2}d$ used **or** $M_1r_1 = M_2r_2$ used (1) Star orbit radius = 0.162×10^{10} [m] (1) (0.171×10^{10} scores 1/2 marks)	2
	(c)		$v = \frac{2\pi r}{T}$ **or** $v = \omega r$ and $\omega = 2\pi f$ **ecf** on *T* and *r* (1) $v = \frac{2\pi\times0.162\times10^{10}}{4.65\times10^{6}}$ [= 2 191] (1) $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ attempted **or** rearranged **ecf** on *v* (1) Answer = 4.8×10^{-12} [m] (1)	4
	(d)		Hotter **or** the Earth is cooler **or** equivalent (1) Due to higher intensity [of e-m radiation] (1) Accept because $5^2 > 20$ **or** similar	2
			Question 7 Total	**[10]**

Question			Marking details	Marks Available
8	*(a)*	(i)	$T = \frac{pV}{nR}$ seen **or** equivalent **or** implied (1) $T = \frac{95000 \times 0.79}{28.9 \times 8.31}$ $(= 312.5\ \text{K})$ (1)	2
		(ii)	$U = \frac{3}{2}nRT$ used **or** 3/2 pV (1) AB = -36 400[J] (1)	2
	(b)	(i)	0	1
		(ii)	Valid method either stated **or** clearly implied (1) Accept area under the graph Answer = - 47 250 [J] (1)	2
	(c)		AB: W = 0; ΔU = -36.4 kJ; Q = -36.4 kJ; ✓ BC: W = 37.6 kJ; ΔU = 33.5 kJ; Q = 71.1 kJ; ✓ CA: W = -47.3 kJ; ΔU = 2.9 kJ; Q = -44.4 kJ; ✓ ABCA: W = -9.7 kJ; ΔU = 0; Q = -9.7 kJ; ✓ **ecf** on ΔU **no ecf** **ecf** on W **ecf** on all if $\Delta U \approx 0$ but must make sense	4
			Question 8 Total	**[11]**

Question			Marking details	Marks Available
1	*(a)*	(i)	Attempt at 6n + 6p - mass of carbon nucleus (1) × 931 and ÷12 **or** $E = mc^2$ and ÷12 (1) Correct answer = 7.7 [MeV/nucleon] **or** 1.23×10^{-12} [J] (1)	3
		(ii)	Conversion of 7.16 MeV to mass = 0.00769 [u] (1) Conservation of mass-energy 4.0015 + 11.9967 - 0.00769 (1) Answer approx correct e.g. 15.99 u accept (16.07 ± 0.08) [u] **or** $(2.67 \pm 0.02) \times 10^{-26}$ [kg] (1) 15.9905 (accuracy mark, also available for 16.0059 and without unit) (1)	4
	(b)	(i)	Neutron absorber **or** high melting point (**or** other valid response)	1
		(ii)	Light nucleus **or** poor neutron absorber **or** slows down neutrons (**or** other valid response)	1
		(iii)	High heat capacity **or** poor neutron absorber **or** doesn't become radioactive (**or** other valid response) Don't accept must be a fluid **or** good ability to conduct heat away	1
			Question 1 Total	**[10]**

Question			Marking details	Marks Available
2	*(a)*	(i)	Mass number = 206 (1) Atomic number = 82 (1)	2
		(ii)	Gas can be <u>inhaled</u> (1) (Don't accept if state both ingest and inhale) **Any 2 (×1) from:** • Dense gas **or** stays in basements • Alpha <u>highly</u> ionising • Multiple emissions i.e. more than 1 alpha (do not accept emits alpha and beta by itself) • Short half-life • Contaminates wells • Enters through cracks Don't accept high activity **or** contaminates water supply **or** alpha particles are breathed in **or** causing cancer	3
	(b)		Use of $\lambda = \frac{ln2}{T_{1/2}}$ e.g. $\lambda = 0.182$ [day^{-1}] (2.11×10^{-6} s^{-1}) **or** $t = nT_{1/2}$ (1) Logs taken correctly e.g. $\ln A = \ln A_0 - \lambda t$ **or** $\ln A = \ln A_0 - n\ln 2$ (1) Algebra correct e.g. $t = \frac{1}{\lambda}\ln\frac{A_0}{A}$ **or** $n = \frac{1}{\ln 2}\ln\frac{A_0}{A}$ **or** implied (1) Correct answer 13.2 [days] (1.14×10^6 [s]) (1)	4
	(c)		Daughter nuclei give added activity	1
			Question 2 Total	**[10]**

Question			Marking details	Marks Available
3	*(a)*	(i)	Values substituted into $C = \frac{\varepsilon_0 A}{d}$ (= 7.32×10^{-9} F) (1) $Q = CV$ (**or** implied) note $C = \frac{Q}{V}$ not good enough (1) Answer = 9.37×10^{-7} [C] (1)	3
		(ii)	Answer = 6.0×10^{-5} [J] (**ecf**)	1
		(iii)	$E = \frac{V}{d}$ (1) Answer = 2 170 000 [V m^{-1}] (1)	2
	(b)	(i)	Capacitance decreases (1) Energy stored increases (1)	2
		(ii)	Work done by separating plates **or** work done against field **or** increase in potential energy (1) (accept energy used instead of work done) Equal to increase in stored energy (1)	2
			Question 3 Total	**[10]**

Question			Marking details	Marks Available
4	*(a)*		$n = \frac{9560}{1.45}$ (1) Correct answer = 2.65×10^{-3} T **UNIT mark** (1)	2
	(b)		$B = \frac{\mu_0 I}{2\pi a}$ used (e.g. 2.82×10^{-6} [T] **or** 4.35×10^{-6} [T] **or** 10^{x} slips) (1) Subtracting **or** adding fields (1) 1.53×10^{-6} [T] no **ecf** (1) Out of paper (1)	4
	(c)		Equating fields e.g. $\frac{\mu_0 \times 0.24}{2\pi \times a} = \frac{\mu_0 \times 0.37}{2\pi \times (0.034 - a)}$ **or** $\frac{\mu_0 \times I_1}{2\pi \times a} = \frac{\mu_0 \times I_2}{2\pi \times b}$ (1) (Accept $\frac{a_1}{a_2} = \frac{0.37}{0.24}$ (= 1.54 or 0.65 reciprocal)) Algebra $\frac{0.24 \times 0.034}{(0.37+0.24)} = a$ **or** $\frac{0.37 \times 0.034}{(0.37+0.24)} = a$ **or** $a = \frac{1.54}{2.54} \times 0.034$ etc (1) Answer = 0.0134 [m] **or** 0.0206 [m] but must be clear from algebra, working **or** statement that the point is nearer the upper wire (1)	3
			Question 4 Total	**[9]**

Question			Marking details	Marks Available
5	*(a)*		$F = Eq$ (**or** eE) used **or** implied (1) $E = \frac{V}{d}$ **quoted or** implied (1) $a = \frac{F}{m}$ used **or** implied (1) $a = \frac{11.2\text{x}1.6\text{x}10^{-19}}{9.11\text{x}10^{-31}\text{x}7.6\text{x}10^{-3}}$ $[= 2.588 \times 10^{14}]$ (1) N.B. Use of $a = \frac{Eq}{m}$ **or** $F = \frac{Vq}{d}$ **award 2 marks or** $a = \frac{Vq}{md}$ **award 3 marks**	4
	(b)	(i)	No horizontal forces (don't accept no horizontal acceleration **or** because it's in a vacuum)	1
		(ii)	Constant vertical force **or** uniform electric field	1
	(c)		Valid method for obtaining time e.g. $s = ut + \frac{1}{2}at^2$ (1) Time correct = 5.4×10^{-9} [s] (1) Answer = $8.00 \times 10^{7} \times 5.4$ ns = 43 [cm] **(ecf)** (1) (factors of 10 or $\sqrt{10}$ slips only penalised 1 mark)	3
	(d)		Valid method e.g. definition of eV, force × distance, getting resultant velocity and finding change in $\frac{1}{2}mv^2$ (1) Answer = 5.6 [eV] (which can simply be written for full marks) **or** 8.96×10^{-19} [J] **(ecf)** (1) (answer of 11.2 eV gets 1/2 marks)	2
			Question 5 Total	**[11]**

Question			Marking details	Marks Available
6	*(a)*	(i)	Flux linkage = $NBA\cos\theta$ used (1) 0.251 [Wb] [and 0.251 Wb] (1)	2
		(ii)	No change in flux [linkage] **or** field lines cut in one direction and then the opposite direction Don't accept rate of change of flux is 0	1
	(b)		Flux linkage = 0.0443 **or** -0.0443 (1) Time = $\frac{20}{360} \times 0.1$ (1) Attempt at change of flux (linkage) divided by time (1) Answer = [-] 15.9 [V] (1)	4
	(c)		Peak emf = 17 [V] Sinusoid with peak of 3.4 squares high (**ecf)** (1) Sinusoid with period of 4 squares (1)	3
			Question 6 total	**[10]**

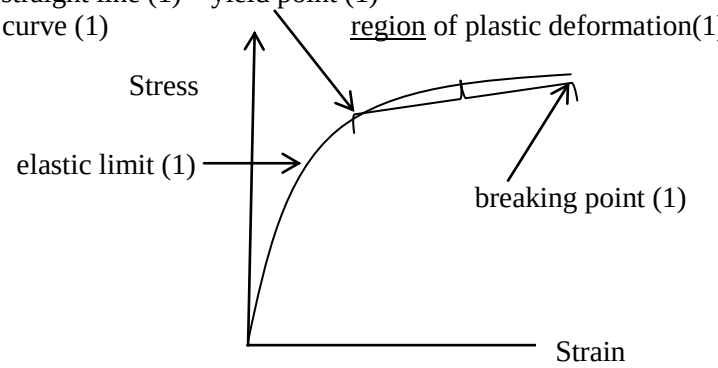
Question			Marking details	Marks Available
7	(a)		**Any 2 (×1) from:** • Near stars move relative to distant stars [due to Earth orbit] • More movement (or larger angle) means stars nearer (inversely proportional etc.) or accept parsec = 1/arcsec • Parallax (or distance) can be measured from readings 6 months apart (or accept readings where Earth movement is known etc.)	2
	(b)		4 parsec **or** angle = $1.5 \times 10^{11}/d$ (1) $4 \times 3.25 = 13$ [light year] (1)	2
	(c)		10× distance gives <u>100 times</u> less intensity (1) Substituting 1 and 0.1 into equation **accept 1 and 10** (1) $m = M - 5$ and $m = M$ shown (1) **Alternative:** 2.5^5 roughly equal to 100 **award 2 marks**	3
	(d)		1[%] Accept 0.01 but not 0.01 %	1
	(e)		Electrons need to be in the high energy levels (1) They need to be in $n = 3$ (1^{st} mark can be implied in the 2^{nd} mark) (1) Not possible because no ultraviolet to absorb **or** collisions don't have enough KE (1)	3
	(f)		Comparison with $4\pi r^2 \sigma T^4$ **or** $b = 4\pi\sigma$ (1) Answer $b = 7.13 \times 10^{-7}$ (1) Unit = W m^{-2} K^{-4} **or** equivalent (1)	3

Question			Marking details	Marks Available
	(g)	(i)	T = 1 (year) and a = 1 (AU) and M = 1 Accept because everything = 1	1
		(ii)	Assuming $M + m \approx 0.32\ M_{\text{Sun}}$ (1) $a = \sqrt[3]{0.32 \times 0.46^2} = 0.41$ [AU] (1)	2
	(h)		Drop when large eclipses small (1) And small eclipses large (1) Bigger drop when the <u>hotter/brighter</u> star is blocked (1) **Award 3 marks** for bigger drop when small in front of large	3
			Question 7 Total	**[20]**

Question			Marking details	Marks Available
8	*(a)*	(i)	Sinusoidal reading on voltmeter @ 0.9 Hz (or across resistor) (1) Sinusoidal (or changing) *B*-field in primary (1) Leads to *B*-field cutting secondary **or** flux changing in secondary (1) emf induced in secondary due to Faraday's (1)	4
		(ii)	Lost flux **or** no iron core **or** low frequency **or** low turns	1
	(b)	(i)	$\omega L = \frac{1}{\omega C}$ **or** $f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ (1) Answer = 4 490 [Hz] (1)	2
		(ii)	V_R = 12 [V] (1) I = 0.067 [A] (1) $V_L = \text{I} \times \omega L$ **or** $V_C = \text{I} \times \frac{1}{\omega C}$ (1) V_L = 71.5 [V] **and** V_C = 71.5 [V] **or** implied e.g. V_C = same (1)	4
8	*(c)*	(i)	$Z = \sqrt{(X_L - X_C)^2 + R^2}$ (1) Z = 581 [Ω] or implied (1) Current $= \frac{12}{581}$ = 21 [mA] (1)	3
		(ii)	Phasor diagram (1) $\tan\theta = \frac{X_L - X_C}{R}$ (this step implies vector diagram if omitted) (1) Answer = 72° **(ecf)** (1) (18° and similar slips gain 1/2)	3
	(d)		$\frac{R}{X_C} = \frac{3}{4}$ (1) $X_C = \frac{1}{2\pi fC}$ **or** $X_C = \frac{1}{\omega C}$ and $\omega = 2\pi f$ **used** (1) Answer = 20 [kHz] (1)	3
			Question 8 Total	**[20]**

Question			Marking details	Marks Available
9	*(a)*	(i)	Ørsted **or** Oersted (accept Orsted)	1
		(ii)	Battery (not cell)	1
		(iii)	**Any 3 (×1) from:** • Current passed through wire **or** pile connected across wire • Compass turned [nearly] at right angles to wire • When compass above wire points in opposite direction • Compass points according to rh grip (or screw) rule • Field lines circle around wire	3
		(iv)	Electric effect arising from magnetism (or from magnet)	1
	(b)	(i)	Vortices shown separated by (smaller) idlers (1) Vortices and/or idlers labelled (1) Rotation shown or stated (1)	3
		(ii)	**Any 2 (×1) from:** • Maxwell used it to predict e-m waves • Maxwell used it to explain magnetic field due to a wire • Maxwell used it to explain [any other e-m effect!] • Its existence is irrelevant / Maxwell didn't suppose it existed	2

Question			Marking details	Marks Available
9	*(c)*	(i)	Produced when sparks occurred between [ball-ended] rods [connected to an induction coil or high voltage]. (1) Detected by sparks occurring across spark-gap between rods or across break in ring. (1)	2
		(ii)	He found spark intensity varied according to orientation of detector rods [relative to transmitter rods]. **or** he interposed metal grille between transmitter and detector, finding spark intensity varied with grille orientation.	1
		(iii)	He used metal reflector to produce stationary wave. (1) He measured distance between nodes [and doubled it]. (1)	2
	(d)	(i)	Time between events in a frame in which the events occur at the same place. **or** time between events as measured by a clock present at both events.	1
		(ii)	$\gamma = 1.01$ (1) $t_B - t_A = 0.5000\ \gamma$ (1) despite mistakes in γ $t_B - t_A = 0.5050$ [s] (1) allow **ecf** on γ arising from slips.	3
			Question 9 total	**[20]**

Question			Marking details	Marks Available
10	*(a)*		Elastic, straight line (1) yield point (1) curve (1) region of plastic deformation(1)  	6
	(b)	(i)	DE broken **or** E bonds with B (1) HG broken **or** H bonds with D (1) Movement of dislocations stated (1) Or all clearly seen from diagrams	3
		(ii)	No dislocations (or equivalent) **or** no grain boundaries Don't accept addition of foreign atoms Don't accept single crystal (stated in question)	1
		(iii)	Any valid use e.g. Turbine blades (don't accept wind turbines), combustion chambers, nuclear reactors, wear resistant materials, rocket engines etc.	1
	(c)	(i)	$\frac{Fl}{2\times10^{11}A_{steel}} = \frac{Fl}{1\times10^{11}A_{brass}}$ (1) Convincing algebra to show $A_{brass} = 2\times A_{steel}$ (1) (**alternative:** force, length and extension all the same 1 mark so brass must have twice the CSA 1 mark only – not fully shown as required)	2
		(ii)	50 [N]	1
		(iii)	$\Delta x = \frac{50\times2}{\left(2.8\times10^{-7}\right)\times2\times10^{11}}$ (1) – substitution (**ecf** on 50 N) Δx = 1.8 [mm] (1) (correct unit required m or mm)	2
		(iv)	E = ½ Fx (1) (accept $\boldsymbol{E = \frac{1}{2}\sigma\varepsilon V}$) E = 0.044 [J] (1) **(ecf** on Δx only)	2
		(v)	Same (1) F and Δx same (1)	2
			Question 10 total	**[20]**

Question				Marking details	Marks Available
11	*(a)*	(i)		Both background and line spectra labelled clearly	1
		(ii)	I	[Inner] electrons [of target element] knocked out / ionised (1)	4
				Electrons from higher energy levels fall to take their place (1)	
			II	Rapid deceleration of <u>electrons</u> (1)	
				On collision with target element / nucleus (1)	
		(iii)		$\lambda = \frac{hc}{eV}$ (or rearrangement in figures) (1)	2
				$\lambda = 2.07 \times 10^{-11}$ [m] (1) Accept 2.1×10^{-11} [m]	
	(b)	(i)		Ultrasound B-scan (1)	6
				Moving pictures/ see organ development **not** 'give a 2D image' (1)	
		(ii)		CT scan (1)	
				Distinguishes soft tissue well (1)	
				Accept MRI cannot be used because of pacemaker	
		(iii)		MRI scan (1)	
				Gives high quality images of soft tissue (1)	
	(c)			Time taken from scale 5 ± 1 [μs] (1)	3
				Distance = 8.2×10^{-3} [m] (1) **(ecf)**	
				Thickness = $\frac{8.2 \text{x} 10^{-3}}{2} = 4.1 \times 10^{-3}$ [m] (1)	

Question			Marking details	Marks Available
11	*(d)*	(i)	QRS wave / R / central spike (1) Bigger / higher /more spiked (1)	2
		(ii)	P wave flatter / P wave extended/ prolonged PR interval / no P wave / smaller P wave / P wider / P lower amplitude	1
		(iii)	Deepening of Q wave / T wave inversion / ST elevation / ST depression {Irregular interval / inverted waves / bigger distance P to QRS to T wave} N.B. any incorrect statement negates the mark	1
			Question 11 total	**[20]**

Question			Marking details	Marks Available
12	*(a)*	(i)	**Any 2 ×(1) from:** • Possible second use as a bridge • Cheap electricity after build • Zero or low CO_2 after built • High output • Predictable output • Sustainable/renewable/reliable energy source that will not run out	2
		(ii)	**Any 2 ×(1) from:** • Only available twice a day (i.e. not a constant output) • Possible huge impact on Severn estuary wildlife • High CO_2 costs to build • Expensive to build (£3k per kW as opposed to £1k per kW coal)	2
	(b)		GPE (PE not good enough) to KE **or** GPE to electrical (1) KE / mechanical to electrical **or** const KE when running (1)	2
	(c)		Mean height increase = 0.5 h must be stated **not** implied (1) Either volume = Ah **or** mass = $Ah\rho$ (1) Correct substitution into mgh **(ecf)** (1)	3
	(d)		Values substituted into equation (1.38×10^{14} J) (1) ×2 (or using time as 12 hrs) and × 0.75 (1) Dividing by time or $P = E/t$ etc. (1) Answer = 2.4 [GW] **(no ecf)** (1)	4

Question			Marking details	Marks Available
12	(e)	(i)	**Any 2 ×(1) from:** • Continuous electricity not twice a day • Less damage to environment • Less impact on shipping	2
		(ii)	Mass per second = $A\rho v$ (or implied) (1) KE per second = 0.5 $A\rho v\, v^2$ (or good attempt at $0.5mv^2$) (1) × 0.75 (1) Answer = 3.1 [GW] **(no ecf)** (1)	4
		(iii)	Because $\propto \lvert v^3 \rvert$(accept v^2, v^3 *etc.*) and we need $\lvert\overline{v^3}\rvert$ not $\lvert\bar{v}\rvert$ Wordy answers also valid e.g. 'if speed is 1.5 and 4.5 say, 4.5^2 will be far more significant than 1.5^2 or 'the power output for high speeds will be far greater than for low speeds increasing the mean power' etc.	1
			Question 12 total	**[20]**

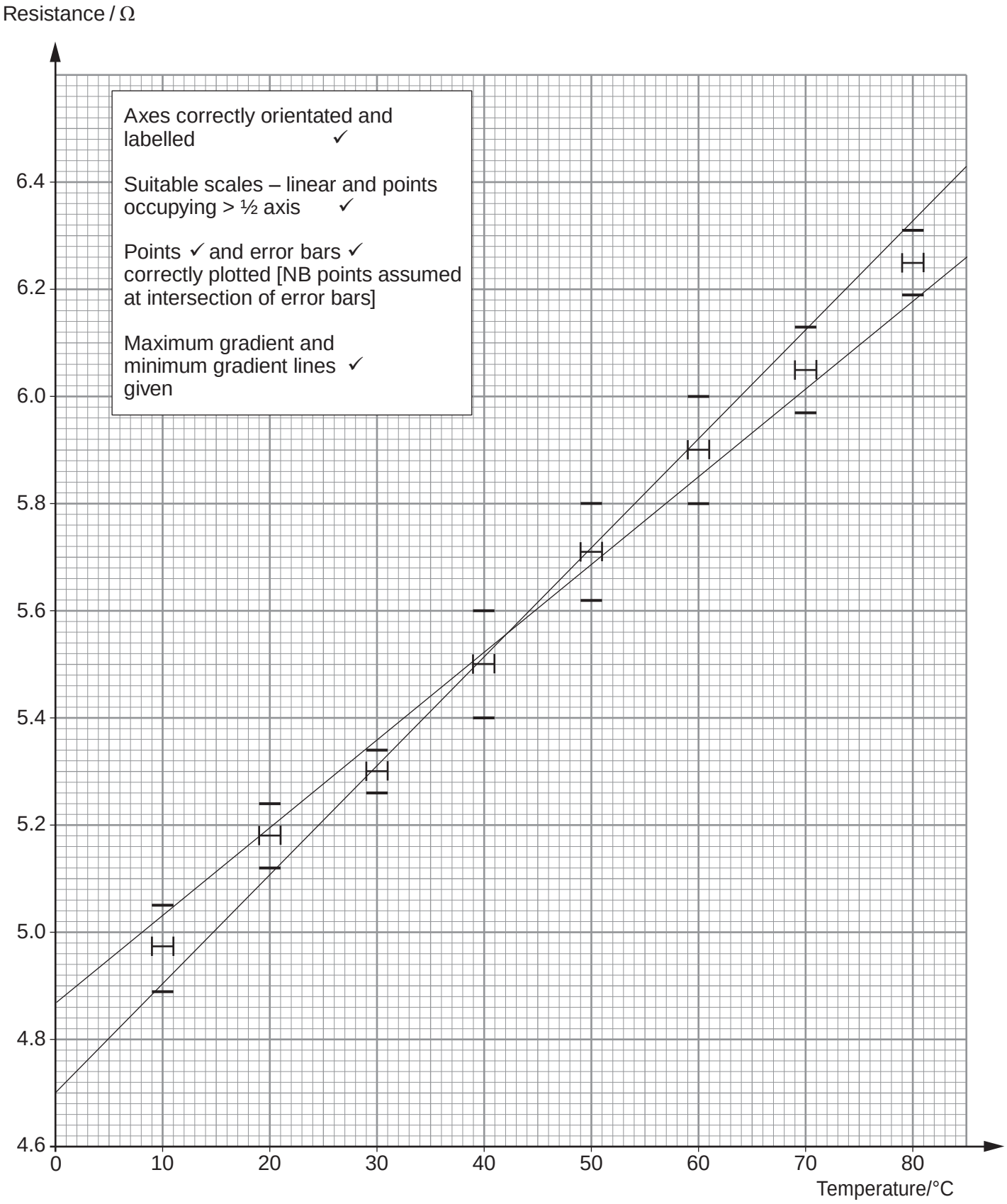
PH6

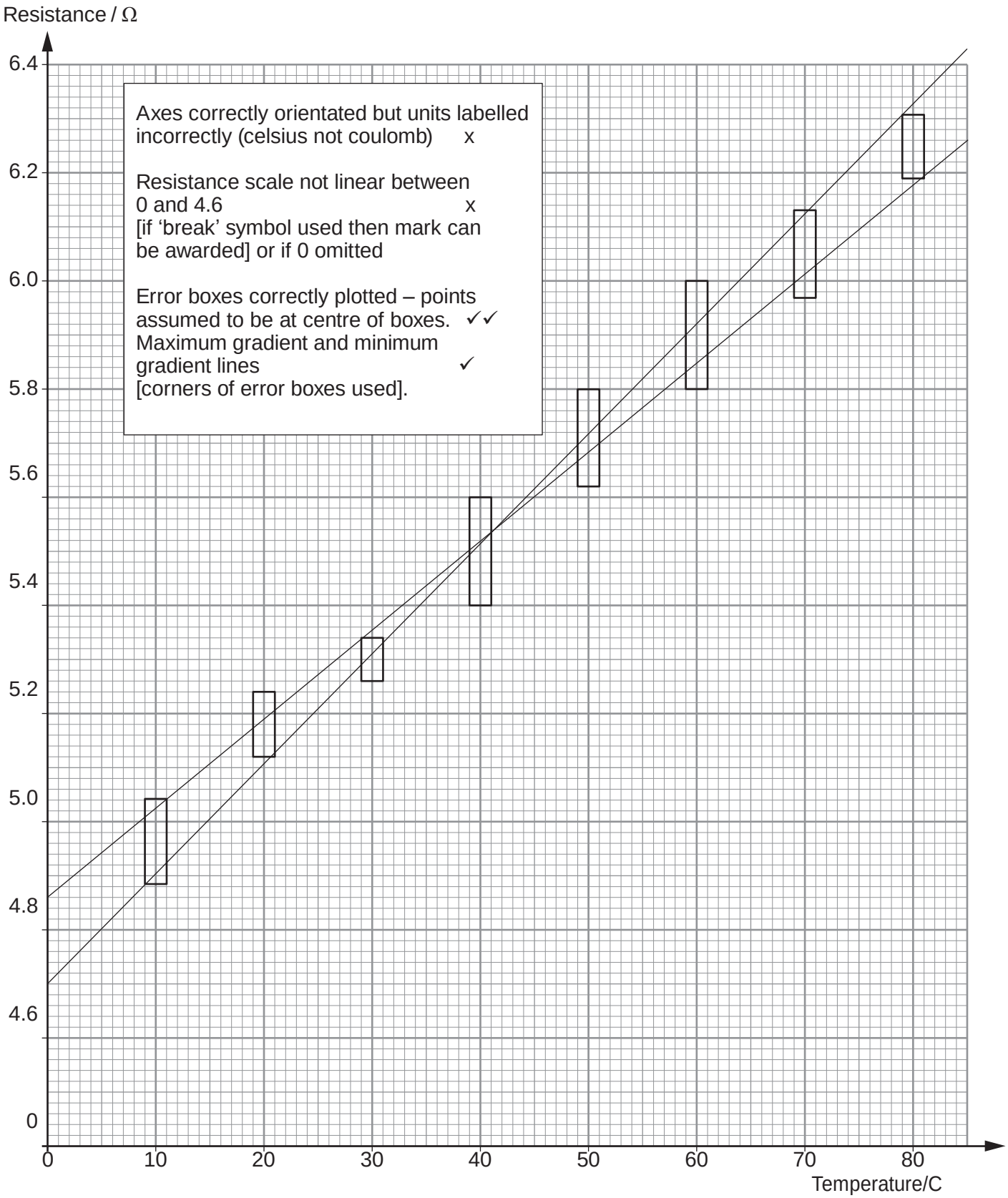
DATA ANALYSIS TASK – Mark Scheme

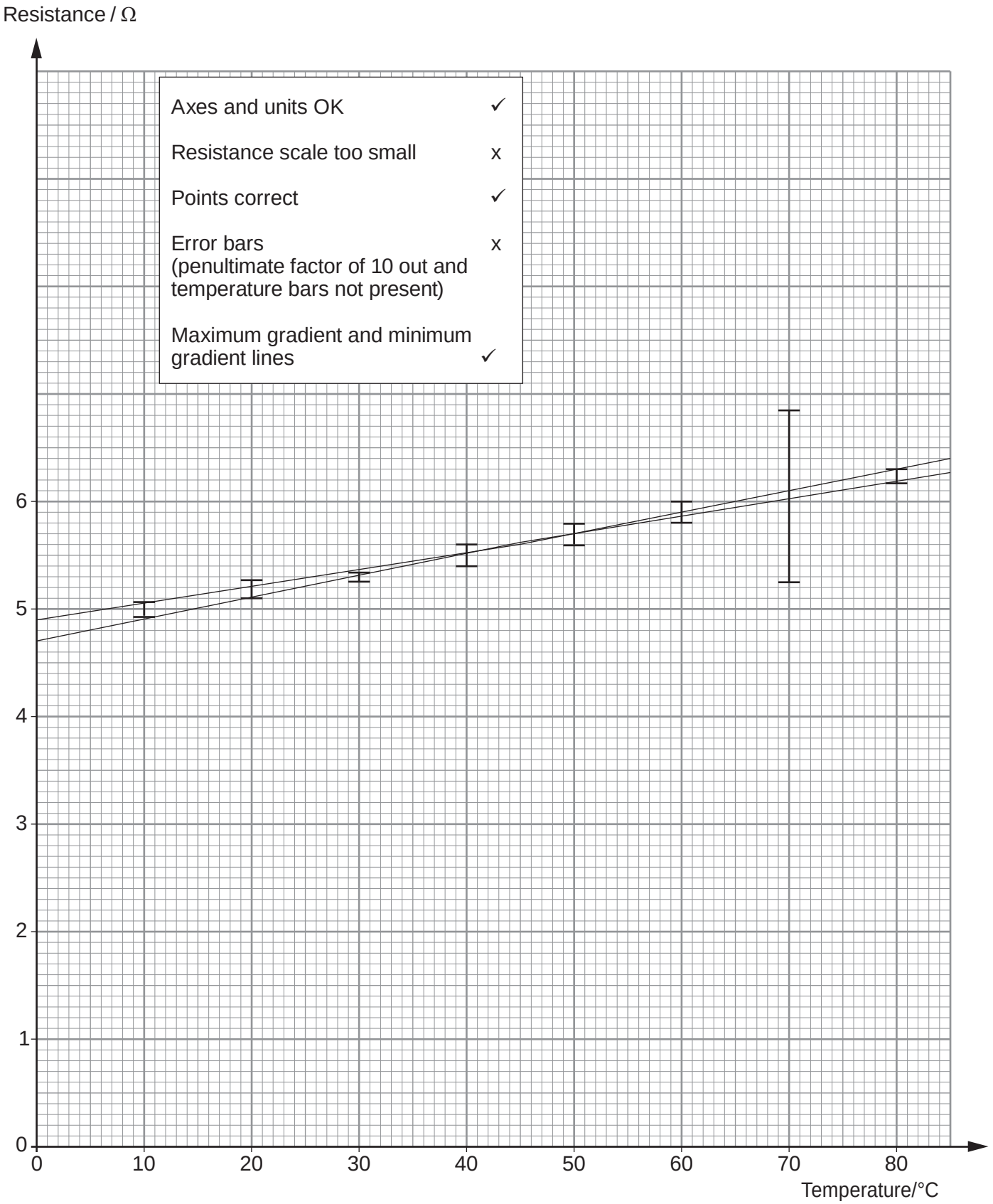
<table>
<tr><th colspan="2">Question</th><th>Marking details</th><th>Marks Available</th></tr>
<tr><td>(a)</td><td></td><td>
<table>
<tr><th>Temperature, θ / °C</th><th>Mean resistance, R_θ / Ω</th><th>Absolute uncertainty / Ω</th></tr>
<tr><td>10 ± 1</td><td>4.97</td><td>0.08</td></tr>
<tr><td>20 ± 1</td><td>5.18</td><td>0.06</td></tr>
<tr><td>30 ± 1</td><td>5.30</td><td>0.04</td></tr>
<tr><td>40 ± 1</td><td>5.50</td><td>0.10</td></tr>
<tr><td>50 ± 1</td><td>5.71</td><td>0.09</td></tr>
<tr><td>60 ± 1</td><td>5.90</td><td>0.10</td></tr>
<tr><td>70 ± 1</td><td>6.05</td><td>0.08</td></tr>
<tr><td>80 ± 1</td><td>6.25</td><td>0.06</td></tr>
<tr><td></td><td>(1)</td><td>(1)</td></tr>
</table>
1 mark for each correct column.
Note all numbers must be identical to those given in the table</td><td>2</td></tr>
<tr><td>(b)</td><td></td><td>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) ecf from (a)
Correct maximum gradient and minimum gradient lines consistent with the error bars. (1)
See exemplification on pages 38-42 for additional guidance on marking this section.</td><td>5</td></tr>
<tr><td>(c)</td><td></td><td>It is a straight-line graph. (1) accept the graph is linear or a comparison with $y = mx + c$
<u>Positive</u> intercept (on the resistance axis). (1)
For the 3rd mark:
Either:
Possible to draw a straight line through all the error bars / boxes. (1) allow ecf from graph
Accept data points
Or
Has a positive gradient. (1)

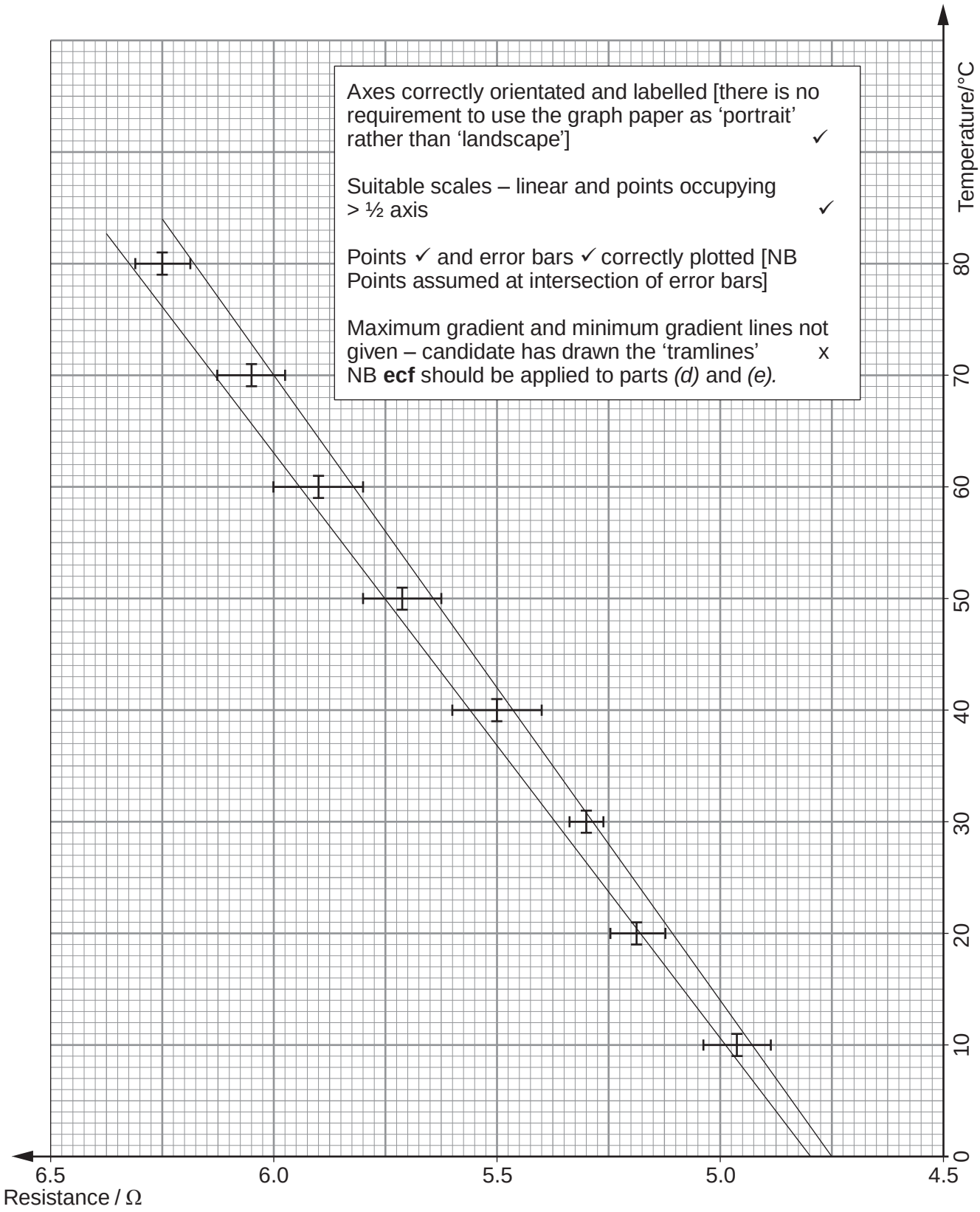
N.B. There is no mark for just “yes it is in agreement”.
Subtract one mark for contradictory conclusion
e.g. “not in agreement” because a straight line with positive intercept through all error bars → 2 marks</td><td>3</td></tr>
</table>

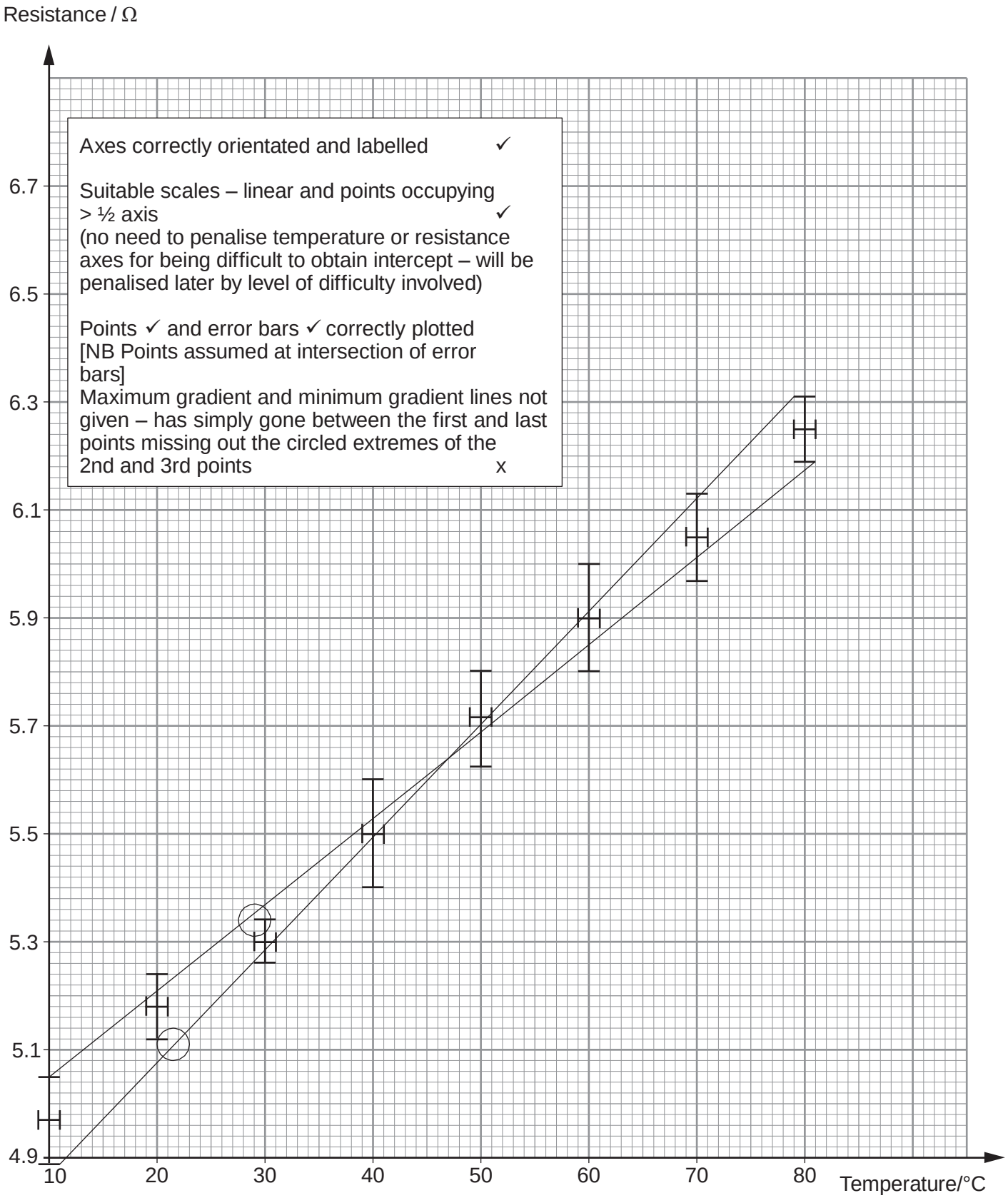
Question		Marking details	Marks Available
(d)	(i)	Large triangles used (should be close to the extremities of the lines) or 2 equivalent suitable points clearly indicated on each line. (1) Both gradients calculated correctly (ignore unit and significant figures) (1 + 1) Allow **ecf** for incorrect max/min 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** and for 3 sig figs in % uncertainty Intercept = Resistance (of copper) **<u>at 0 °C.</u>** (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) apply **ecf** [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. $0.0039 \pm 0.0005\ °C^{-1}$; $(3.9 \pm 0.5) \times 10^{-3}\ °C^{-1}$]. (1) Award the mark if α and absolute uncertainty calculated correctly but written separately.	3
		Question total	**25**











Question		Marking details	Marks Available
(a)		$\ln T = n \ln d + \ln k$ (1) Graph of $\ln T$ (y-axis) against $\ln d$ (x-axis) stated to be plotted or explicit comparison with $y = mx + c$ (1) (accept any logarithm) *Remember not to award the marks if the information sheet was issued.*	2
(b)		Explain or state a method to ensure the threads are vertical **or** explanation of thread movement to ensure symmetry implied. (1) accept reference to paired readings or ruler being horizontal Minimum of 5 readings between and including the range 30 cm to 60 cm. (1) Minimum of 5 oscillations timed for each value of d. (1) Repeat readings taken. (1) **All of the above points cannot be awarded from the table they must be stated in their plan.**	4
(c)		Single, clear, main table with titles and units on each column. (1) Accept if candidates have recorded d in m or cm. N.B. log values should have no unit e.g. $\ln(T/\text{s})$ is acceptable, however $\ln T/\text{s}$ and $\ln T/\ln \text{s}$ are both not acceptable. Repeat readings given and mean values correct. (1) Period of 1 oscillation calculated correctly and to 3/4 sig figs. **ecf** (1) The resolution of the ruler given as ±1 mm and the stopwatch as ± 0.01 s: can be awarded from plan (1) **All** log values calculated correctly to 2 decimal places (accept 3 dp) **and** d to nearest mm (1)	5
(d)		Graph of $\ln T$ against $\ln d$ plotted with axis labelled and no units (**ecf** units from table). (1) Suitable scale so that data points occupy at least half of each axis. (1) All points plotted correctly to within ½ small square division. (1) Good line of best fit consistent with the data. (1)	4
(e)		Large triangle used (should be close to the extremities of the line of best fit i.e. over half the line used) [or 2 equivalent suitable points clearly indicated on the graph]. (1) Gradient calculated correctly including negative sign. (1) Gradient = n clearly stated. (1)	3
(f)	(i)	Yes - **with 2 × (1) of the following points:** (N.B. gradient in *(e)* must be between 0.70 to 1.30) • **Gradient** is negative; (1) • **Gradient or n** is approximately / equal to 1;(1) • Inversely proportional or T is proportional to d^{-1}. (1) **Alternative:** Yes because n / gradient = –1. (2) N.B. no **ecf** allowed from the graph or part *(e)* i.e. if graph is wrong and value of n is wrong they lose these 2 marks. (Yes on its own = 0 marks.) **Award a maximum of 2 marks only.**	2
	(ii)	Rearrangement $b = \dfrac{T^2 d^2}{4\pi^2 l}$ (1) Correct calculation of b using points taken from their table. (1) Units cm s² (accept m s² if consistent with calculation). (1)	3
	(iii)	Increase / become longer. (1) by $\sqrt{2}$. (1)	2
		Question total	**[25]**

MARK SCHEME – TEST 2
Same as for TEST 1

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