GCE A LEVEL MARKING SCHEME

SUMMER 2023

A LEVEL
PHYSICS – COMPONENT 2
A420U20-1

INTRODUCTION

This marking scheme was used by WJEC for the 2023 examination. It was finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conference was held shortly after the paper was 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 conference was to ensure that the marking scheme was 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' conference, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about this marking scheme.

GCE A LEVEL PHYSICS

COMPONENT 2 – ELECTRICITY AND THE UNIVERSE

SUMMER 2023 MARK SCHEME

GENERAL INSTRUCTIONS

<u>Recording of marks</u>

Examiners must mark in red ink.

One tick must equate to one mark (except for the extended response question).

Question totals should be written in the box at the end of the question.

Question totals should be entered onto the grid on the front cover and these should be added to give the script total for each candidate.

<u>Marking rules</u>

All work should be seen to have been marked.

Marking schemes will indicate when explicit working is deemed to be a necessary part of a correct answer.

Crossed out responses not replaced should be marked.

Credit will be given for correct and relevant alternative responses which are not recorded in the mark scheme.

<u>Extended response question</u>

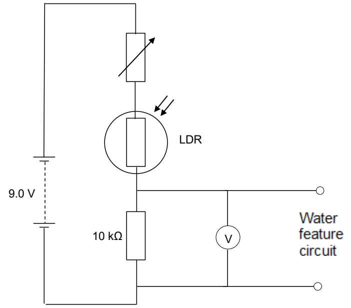
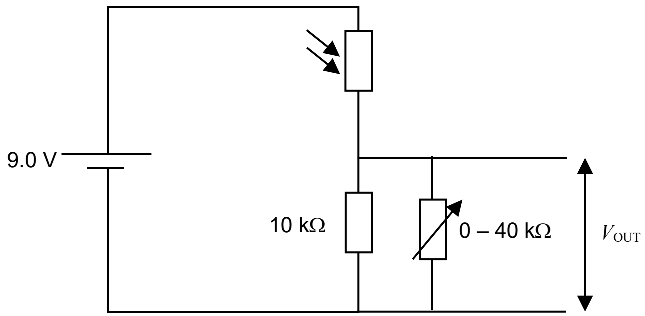
A level of response mark scheme is used. Before applying the mark scheme please read through the whole answer from start to finish. Firstly, decide which level descriptor matches best with the candidate's response: remember that you should be considering the overall quality of the response. Then decide which mark to award within the level. Award the higher mark in the level if there is a good match with both the content statements and the communication statement.

Marking abbreviations

The following may be used in marking schemes or in the marking of scripts to indicate reasons for the marks awarded.

cao	=	correct answer only
ecf	=	error carried forward
bod	=	benefit of doubt

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
					Marks available					
1	(a)			[Electrical] energy transferred [to other forms] per unit [accept coulomb] of charge [passing between the two points]	1			1		
	(b)	(i)		[Resistance across LDR decreases as light intensity increases - no mark, information already given] pd across LDR decreases **or** pd across fixed resistor increases [in daylight] (1) So reading on voltmeter increases (1) **Because**: **Either -** ratio of pds across potential divider changes / greater share of pd across fixed resistor **or** - Total pd must = 9.0 V (or equivalent) (1) **OR (current alternative)** Overall resistance decreases **or** since $I \propto \frac{1}{R}$ (1) Current increases (1) So pd for voltmeter increases (1)		3		3		
		(ii)		Substitution: $\frac{2}{9} = \frac{10}{(10 + R_{\text{LDR}})}$ (1) R_{LDR} = 35 k[Ω] (1) **OR** $\frac{2}{7} = \frac{10}{R_{\text{LDR}}}$ (1) R_{LDR} = 35 k[Ω] (1)	1	1		2	1	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
				Alternative: Current = $\frac{2.0\text{ V}}{10\text{ k}\Omega}$ (1) [= 0.20 mA] $R_{\text{LDR}} = \frac{(9.0-2.0)\text{ V}}{0.2\text{ mA}}$ = 35 k[Ω] or $R_{\text{LDR}} = \frac{(7.0)\text{ V}}{0.2\text{ mA}}$ = 35 k[Ω] (1)						
		(iii)	I	Variable resistor positioned appropriately **and** correct symbol (labelling not required) e.g.  **OR** accept in parallel with 10 kΩ  			1	1		

Question				Marking details	AO1	AO2	AO3	Total	Maths	Prac
					Marks available					
			II	**SERIES CIRCUIT** **Either:** Max variable R + LDR resistance in full sunlight seen (= 40.2 kΩ) (1) V_{out} shown = 1.8 [V], so yes (1) **Or:** Variable resistor value determined at activation voltage in full sunlight (2 V) (= 34.8 kΩ) (1) Hence variable resistance can be increased further to reduce V_{out} to below activation voltage, so yes (1) **Alternative:** Maximum resistance = 40 + 10 + 0.2 kΩ [= 50.2 kΩ] (1) $\rightarrow$ minimum current = $\frac{9.0\text{ V}}{50.2\text{ k}\Omega}$ [=0.18 mA] $\therefore$ Minimum $V_{10\text{ k}\Omega}$ = 0.18 mA × 10 kΩ = 1.8 [V] This is less than activation voltage / 2.0 [V] so yes (1) **Alternative:** The top resistance has to be less than 35 kΩ for V_{out} to be more that 2.0 [V] (1) so turning up the variable resistor to 40 kΩ will always turn off the feature (1) **PARALLEL CIRCUIT:** If V_R resistance adjusted to zero (1) the total resistance of the V_R / 10 kΩ combination tends to 0 $\therefore$ pd across V_R / 10 kΩ tends to 0 and the water feature is off (1)			2	2	1	

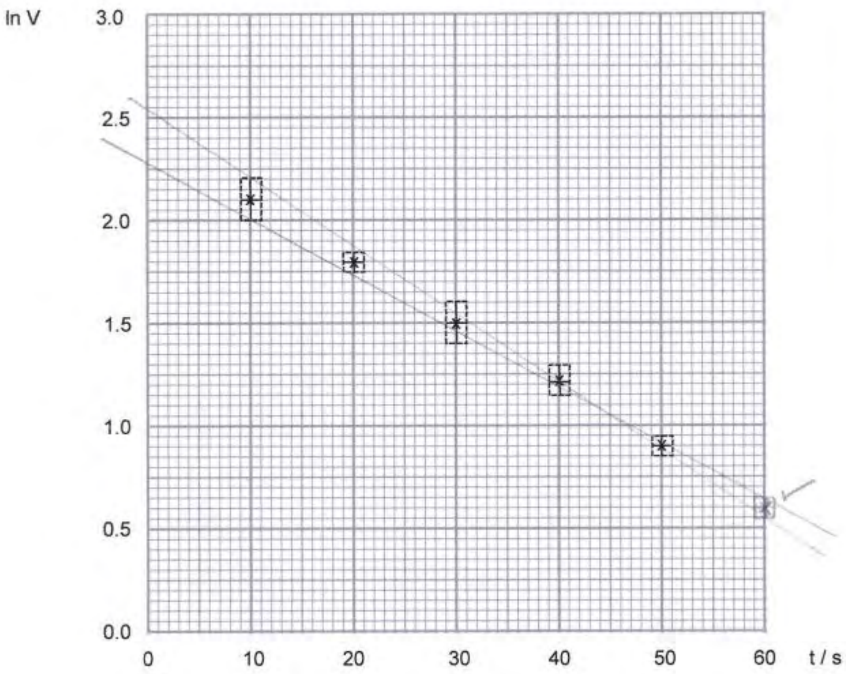
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
				Or To achieve [less than] 2 V across water feature circuit, resistance of V_R / 10 kΩ combination must be [less than] 57.1 Ω (1) ∴ This can be achieved if V_R < 57.1 Ω, so possible (1)						
				Question 1 total	**2**	**4**	**3**	**9**	**2**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	(a)		Collisions between [free] electrons and {[copper] ions / atoms / molecules / lattice} Accept prevent / impede for collisions	1			1		
	(b)	(i)	Free electrons in wire = $\frac{1\times 36\times 10^{-3}}{1.05\times 10^{-25}}$ (1) [= 3.4 × 10^{23}] $n = \frac{3.4\times 10^{23}}{4\times 10^{-6}}$= 8.57 × 10^{28} [m^{-3}] seen (1) Award 2 marks for single step calculation if 8.6 × 10^{28} [m^{-3}] seen **Alternative:** Density = $\frac{36 \times 10^{-3}}{4 \times 10^{-6}}$ = 9 × 10^3 [kg m^{-3}] (1) No of free electrons per m^3 = $\frac{9 \times 10^3}{1.05 \times 10^{-25}}$ = 8.57 × 10^{28} [m^{-3}]	1	1		2	2	
		(ii)	Substitute $R = \frac{\rho l}{A}$ into $I = \frac{V}{R}$ – any format e.g $I = \frac{VA}{\rho l}$ **or** $V = \frac{I\rho l}{A}$ (1) Hence substitute above into $v = \frac{I}{nAe}$ – any format e.g $v = \frac{VA}{\rho l nAe}$ **or** $\frac{VA}{\rho l} = vnAe$ (1) Correct algebra etc to show $v = \frac{V}{\rho l n e}$ (1)		3		3	3	

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
		(iii)	Substitution (1) $v = 2.45 \times 10^{-3}$ m s^{-1} (if $n = 9 \times 10^{28}$ used) **or** 2.57×10^{-3} m s^{-1} (if $n = 8.57 \times 10^{28}$ used) **unit mark** (1)	1	1		2	2	
	(c)		'n' is the 'same as' **and** drift velocity should be 'less than' (1) Statement or implication that others are correct i.e. A and ρ (1)			2	2		
	(d)		**Any 2 × (1) from:** • Reduced energy loss during transmission / component use • Significant increase in amount of electricity transmission / higher current / there is a current without a source at 273 K • Greater efficiency / reduced size of energy equipment / easier to use / more widespread use of technology • Cheaper / cost savings from greater efficiency • Reduced generation requirement / leading to reduced CO_2 emissions / benefits environment • Accept other valid points e.g. no need to store generating equipment in liquid nitrogen			2	2		
			Question 2 total	**3**	**5**	**4**	**12**	**7**	**0**

<table>
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>3</td><td>(a)</td><td></td><td>• Close S_1 [to charge C]
• Open S_1 and close S_2 to discharge (1)
• [Start stopwatch] and record V at [regular] intervals e.g. every 10 s (1)</td><td>3</td><td></td><td></td><td>3</td><td></td><td>3</td></tr>
<tr><td></td><td>(b)</td><td></td><td><table><tr><th>t / s</th><th>$V_{\text{reading 1}}$ / V</th><th>$V_{\text{reading 2}}$ / V</th><th>ln ($V_{\text{reading 1}}$ / V)</th><th>ln ($V_{\text{reading 2}}$ / V)</th><th>Mean ln(V / V)</th></tr><tr><td>60 ± 1</td><td>1.73</td><td>1.92</td><td>0.55</td><td>0.65</td><td>0.60</td></tr></table>Both quantities determined correctly (1) no sig fig penalty
Point plotted correctly and error bars correctly drawn - t: ± 1; ln V: ± 0.05 [Both equivalent to one small square] (1)</td><td></td><td>2</td><td></td><td>2</td><td>2</td><td>2</td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>Max and min gradients drawn correctly [see below] (1)
Maximum gradient = [-] 0.033 ± 0.001 (1)
Minimum gradient = [-] 0.027 ± 0.001 (1) (ecf on gradient lines)</td><td></td><td>3</td><td></td><td>3</td><td>3</td><td>3</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Mean gradient calculated correctly using answers to (c)(i): 0.030 (1) ecf
% uncertainty in mean calculated: 10% (1) ecf no sig fig penalty</td><td></td><td>2</td><td></td><td>2</td><td>2</td><td>2</td></tr>
</table>

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(d)	(i)	$m = \frac{1}{CR}$ or equivalent identified e.g. $C = \frac{1}{mR}$ (1) $\frac{1}{0.03\ \mathbf{ecf} \times 6.8 \times 10^3}$ **or** 4.9×10^{-3} F (1) (may award 1st mark by implication) **Alternative for the 1st 2 marks:** C calculated using the time constant Total % uncertainty = 15% (**ecf** from (c)(ii)) (1) Absolute uncertainty = $0.7[4] \times 10^{-3}$ (1) **ecf** $C = (4.9 \pm 0.7) \times 10^{-3}$ [F] (1) sig figs must match and no more than 2 sig figs for the uncertainty			5	5	5	5
		(ii)	Mean intercept e.g. 2.4 ± 0.2 (1) (or max and min intercepts determined and mean value calculated) V determined based on first mark e.g. 11.0 ± 1.2 V (1) No sig fig penalty			2	2	2	2
			Question 3 total	**3**	**7**	**7**	**17**	**14**	**17**


ln V
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
t / s

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	(a)	(i)	Pre-stressed bar drawn horizontally inside concrete beam, towards lower surface (below mid-point)		1		1		
		(ii)	Bar puts [lower] surface under compression (accept no longer under tension) (1) Inhibits crack propagation (1) Don't accept reference to dislocations	2			2		
	(b)	(i)	Same [initial] gradients [in elastic phase]		1		1		
		(ii)	Carbon in lattice (1) Accept foreign atom … opposes dislocation movement (1) Don't accept planes of atoms sliding over each other or movement of atoms Hence high carbon steel has greater {strength / stiffness} **or** low carbon steel is more {malleable / softer} (1)	1 1	1		3		
	(c)	(i)	CSA = 4.5×10^{-4} [m^2] (1) Tension in cable = $\dfrac{4.4 \times 10^3}{\cos 20}$ [= 4 682.4 N] (1) Substitution: $\Delta l = \dfrac{(4\,682.4 \times 40)}{(4.5 \times 10^{-4} \times 210 \times 10^9)}$ (**ecf** on A and T) (1) Δl = 1.97 mm seen (answer gains full marks) (1) Award 3 marks for 1.74 [mm] **Alternative:** Use Δl = 2 mm to confirm either E or d or l	1	1 1 1		4	3	

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
		(ii)	Substitution into $E = ½\,F\Delta l$ (1) **ecf** on F and Δl E = 4.6 [J] (1) E = 4.7 [J] if 2 mm used **Alternative:** Use of $E = ½\,kx^2$ (1) E = 4.6 [J] (1)	1	1		2	1	
		(iii)	Quenched alloy steel – High breaking stress / able to withstand greater tension (1) and will extend less / remain elastic / not break (1) **Or (converse):** Low carbon steel - Lower breaking stress / able to withstand less tension (1) and will extend more / plastic region / or break (1)			2	2		
			Question 4 total	**6**	**7**	**2**	**15**	**4**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	(a)		**Indicative content:** The curves from both the Earth and the Moon tend towards a potential of zero. This is because by convention the potential at infinity (a point where the system has no influence) is taken to be zero J/kg. As a mass enters either (or both) gravitational fields, the field does work on the mass, and it loses potential energy. i.e it gains increasing negative values. [Alternative - Work needs to be done on an object to move away from the Earth/Moon/System i.e it must be given energy to raise its potential (energy) to zero]. The potential at the surface of the Earth has a bigger (negative) value than at the surface of the Moon. Potential due to an object (planet/moon) of Mass M is proportional to the Mass of the object and inversely proportional to the distance from its centre (or could be expressed in terms of the potential equation). Since the Mass of the Earth is significantly greater than that of the Moon, the (negative) potential at its surface is greater. [Greater Earth radius has less of an effect]. The value of the gradient at any point gives the value of 'g' at that point. The gradient decreases with distance, indicating that 'g' decreases with distance. The gradient near the Earth's surface is steeper than near the Moon's surface indicating that g is greater at the surface of the Earth. The value of the combined potential at any point is the sum of the individual potentials due to the Earth and Moon. The value of the combined potential represents the energy needed for 1 kg to escape from the system (to reach infinity). At point X, the combined value of the gradient is zero. At this point g_{Earth} = (-) g_{Moon} and represents the point in space where the least amount of energy is needed to escape the system. The difference in potential at the Earth's surface and that at X is the minimum energy needed (per kg) for an object fired from earth to reach the Moon.	3	3		6		

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
			5-6 marks Comprehensive description given for all 3 curves. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured* **3-4 marks** Comprehensive description given for 2 out of the 3 curves or a limited description of all 3. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Limited description given for 1 or 2 of the curves. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*						
	(b)	(i)	Initial $E_K + E_P$ at surface = E_P in orbit (however expressed) (1) Substitution, algebra and correct use of signs (2) (Subtract 1 for incorrect use of signs) $\frac{1}{2}u^2 - \frac{(6.67 \times 10^{-11} \times 6.4 \times 10^{23})}{3.4 \times 10^6} = -\frac{(6.67 \times 10^{-11} \times 6.4 \times 10^{23})}{3.7 \times 10^6}$ u = 1430 [m s^{-1}] (1) **OR** Using mgh – award a maximum of 3 marks **OR** Using mean g at height of 150 km **and** calculating u = 1426 [m s^{-1}] award 4 marks	 1	1 1 1		4	3	

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
		(ii)	Application of $\frac{GM}{r^2} = \frac{v^2}{r}$ or equivalent or by implication (1) Substitution (1) v = 3.4 × 10^3 [m s^{-1}] seen (1) no conclusion required **Alternative:** Use of $T^2 = \frac{4\pi^2 r^3}{GM}$ (1) to give T = 6844 [s] (1) Use of $v = \frac{2\pi r}{T}$ so v = 3.4 × 10^3 [m s^{-1}] (1)	1	1 1		3	3	
			Question 5 total	**5**	**8**	**0**	**13**	**6**	**0**

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
6	(a)		Individual field strength magnitudes correctly calculated for all charges [200 N C^{-1}, 800 N C^{-1}, 400 N C^{-1}, 300 N C^{-1}] (2) (Subtract 1 mark for each incorrect value of magnitude - 0 for two or more incorrect values) Horizontal and vertical components determined [500 N C^{-1} upwards and 1 200 N C^{-1} to the left] [**ecf**] (1) Resultant magnitude: 1 300 [N C^{-1}][**ecf**] (1) Direction: 67.4° to left of vertical or 22.6° above horizontal (**ecf**) (1) must be clearly shown	1	1 1 1 1		5	4	
	(b)		Use of potential equation $V = \frac{kQ}{r}$ (1) All individual potential values correctly calculated for all charges [-60 V, -120 V, +240 V, +90 V] (1) Clearly shown to be +150 V **ecf** (1)	1	1 1		3	2	
	(c)		$\frac{1}{2} mv^2 = q\,(\Delta V)$ or by implication e.g. $v^2 = \frac{2 \times 1.6 \times 10^{-19} \times (150 - 50)}{9.11 \times 10^{-31}}$ (**ecf** on V from (b)) (1) $v = 5.9 \times 10^6$ [m s^{-1}] (1) v = 2% of c calculated and comment made (1)			3	3	3	
			Question 6 total	**2**	**6**	**3**	**11**	**9**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)		Similar pattern i.e. line spacing (by eye) (1) All shifted to the right by same degree (1)	1	1		2		
	(b)	(i)	$\lambda = 4.8 \times 10^{-7}$ [m] (1) Visible (1) accept blue	1	1		2	1	
		(ii)	Substitution, including for correct surface area: $P = 5.67 \times 10^{-8} \times 4 \times \pi \times (3.15 \times 10^{10})^2 \times (6000)^4$ (1) $P = 9.2 \times 10^{29}$ W **unit mark** (1)	1	1		2	1	
	(c)		Evidence of changes incorporated in Stefan equation: e.g. $3P = \sigma \times 4\pi \times d^2 \times T_N^4$ (1) Comparison with original conditions (e.g. $P = \sigma \times \pi \times d^2 \times T_0^4$) and correct algebra (1) $T_N = \left(\frac{3}{4}\right)^{\frac{1}{4}} T_0$ shown or factor 0.9[3] seen (or 1.08) and little change to temperature (hence less than 10%) (1) **Alternative:** New $A = 4\pi \times (6.3 \times 10^{10})^2 = 4.99 \times 10^{22}$ so $P = 3 \times 9.2 \times 10^{24} = 2.76 \times 10^{30}$ (1) $T = \sqrt[4]{\frac{2.76 \times 10^{30}}{4.99 \times 10^{22} \times 5.67 \times 10^{-8}}}$ = 5588.6 [K] (1) Then $\frac{6000 - 5588.6}{6000}$ = 6.8% (hence less than 10%) (1)			3	3	3	
			Question 7 total	**3**	**3**	**3**	**9**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	(a)	(i)	Some context e.g. consider matter within shell of radius R (assuming homogenous universe) Mass within shell = $\frac{4}{3}\pi R^3 \times \rho$ (1) $\frac{1}{2} mv^2 - \frac{GMm}{R} = 0$ (or equivalent) (1) Substitution of $v = H_0R$ (or equivalent, e.g. H_0D) (1) Convincing algebra (1) N.B. Subtract 1 mark if no context provided	4			4	2	
		(ii)	$5 \times 1.66 \times 10^{-27} = 8.3 \times 10^{-27}$ [kg m^{-3}] **or** mass of 1 mole of H = 1×10^{-3} therefore mass of 1 atom = $\frac{1 \times 10^{-3}}{6.02 \times 10^{23}} = 1.66 \times 10^{-27}$ [kg] so ρ_c is: $\times 5 = 8.3 \times 10^{-27}$ [kg m^{-3}] (1) Substitute and re-arrange: $H_0 = \left(\frac{8\pi G \times 8.3 \times 10^{-27}}{3}\right)^{\frac{1}{2}}$ (1) **ecf** $H_0 = 2.15 \times 10^{-18}$ [s^{-1}] – correct / same to 2 sig figs (1) **Alternative:** accept converse argument			3	3	2	
	(b)	(i)	$3.2 \times 10^9 \times 9.5 \times 10^{12} = 3.0 \times 10^{22}$ k[m] (1) Substitution and answer into $v = H_0D$, v = 66 880 [km s^{-1}] (or similar seen or 65 360 if H_0 from a(ii) used) (1) **OR** Hubble constant 68 km s^{-1} per Mpc (1) And 3.2×10^9 is approx 1000 Mpc (1)	1	1		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	$\frac{v}{c}$ calculated (= 0.22) **OR** $\frac{3.2}{13.79} = 0.23$ **OR** $\frac{3.2}{14} = 0.23$ (1) $\Delta\lambda$ = 0.22 × 656.3 × 10^{-9} = 144.4 n[m] **OR** 0.23 × 656.3 = 150.9 n[m] (1) Observed λ = 800.7 n[m] **OR** 807.2 n[m](1) Answer will depend on value of v used from (b)(i) N.B. Deduct 1 mark for slips in powers of 10		3		3	2	
	(c)		Emissions / radiation / wavelengths from the galaxy will be beyond the visible spectrum (range of wavelengths noted) (1) Hubble more able to see these details / can detect this wider range therefore better than other telescopes (1)	1	1		2		
			Question 8 total	**6**	**5**	**3**	**14**	**8**	**0**

A LEVEL COMPONENT 2: ELECTRICITY AND THE UNIVERSE

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	2	4	3	9	2	0
2	3	5	4	12	7	0
3	3	7	7	17	14	17
4	6	7	2	15	4	0
5	5	8	0	13	6	0
6	2	6	3	11	9	0
7	3	3	3	9	5	0
8	6	5	3	14	8	0
TOTAL	**30**	**45**	**25**	**100**	**55**	**17**