COMPONENT 2 – ELECTRICITY AND THE UNIVERSE

MARK SCHEME

GENERAL INSTRUCTIONS

The mark scheme should be applied precisely and no departure made from it.

<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

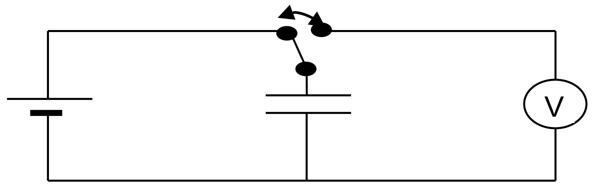
Question			Marking details	Marks available					
				AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
1	*(a)*		n – number of free electrons per unit volume [accept m^{-3}] (1) Accept 'free electron density' v – drift velocity [of free electrons] (1)	1 1			2		
	(b)	(i)	mass = 8 920 $\times$ 2.0 $\times$ 2.0 x 10^{-6} (1) [= 0.0357 kg] $\frac{0.0375}{1.05\text{x}10^{25}} \times 1.5 = 5.1 \times 10^{23}$ electrons (1)		1 1		2	2	
		(ii)	$n = \frac{5.1\text{x}10^{23}(\text{ecf})}{4.0\text{x}10^{6}(\text{ecf})}$ (1) [= 1.28×10^{29} m^{-3}] $v = \frac{1.2}{1.28\text{x}10^{29}\text{x}2.0\text{x}10^{-6}\text{x}1.6\text{x}10^{-19}}$ (subst) (1) [**ecf** on n] $v = 2.9 \times 10^{-5}$ [m s^{-1}] (1) [N.B. use of 5.1×10^{23} for $n \rightarrow$ 7.3[5] [m s^{-1}]	1	1 1		3	2	
	(c)		Correct strategy – determining n for each material (1) n calculated correctly for each material (1) A – 5.95×10^{28} B – 8.30×10^{28} C – 5.98×10^{28} Therefore B made from different material (1) **Alternative solution:** Correct strategy – realisation that e is constant (1) $\frac{I}{Av}$ calculated correctly for each material (1) Therefore B made from different material (1)		1	1 1	3	2	
			Question 1 total	**3**	**5**	**2**	**10**	**6**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	**Diagram or set-up** D1 – Wire shown along with movable contact (accept crocodile clip). D2 – Metre ruler. D3 – Method for measuring resistance shown e.g. correct circuit with ohmmeter or correct circuit with voltmeter and ammeter appropriately connected. D4 – Micrometer or digital callipers or vernier scales. **Method** M1 – Vary length. M2 – Measure resistance (or I and V). M3 – Measure diameter or thickness. M4 – Repeat readings of resistance and length and the mean values obtained. M5 – Repeat readings of diameter (or thickness) and the mean value obtained. M6 – Diameter (thickness) measured in different places along the wire. M7 – Measure zero error of ohmmeter. **Results** R1 - Plot graph of resistance against length. R2 – Measure gradient. R3 – Intercept should be zero. R4 - $\rho = \frac{RA}{l}$ quoted. R5 - ρ = gradient $\times$ area *R6* – Area = πr^2 where $r = \frac{d}{2}$ **5-6 marks** All of D1 – D4 present. All of M1 – M3 and M5 and either M6 or M7 present. All of R1, R2, R4, R5 and R6 present.	6			6		6

			There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** Expect any 3 from D1 – D4. Expect M1, M2 and M3. Expect R1, R2 and R4. There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure. **1-2 marks** Expect any 2 from D1 – D4. Expect M1 and M2. Expect R1. 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.						
		(ii)	Substitution into $R = \frac{\rho l}{A}$ (1) $\rho = 1.06 \times 10^{-7}$ [Ω m] (1)	1	1		2	2	
	(b)		Because $R \propto \frac{1}{A}$ [for equivalent lengths] (1) Therefore there is an increased resistance [per metre] (1) Therefore higher values of R for equivalent lengths lead to a **steeper gradient** (1) Resistivity does not change because the material of the wire does not change (1)		1	1 1 1	4		4
			Question 2 total	**7**	**2**	**3**	**12**	**2**	**10**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*	(i)	V is the terminal pd – or clear explanation in energy terms: energy per coulomb transferred in the external circuit / [N.B. "per coulomb" / "per unit charge" required on one of (i) and (ii) if energy explanation given]	1			1		
		(ii)	pd across the internal resistance [accept lost volts – "bod"] / energy per coulomb lost / dissipated in the internal resistance / cell	1			1		
	(b)	(i)	2.4 [V]	1			1		
		(ii)	0.4 [Ω] [allow **ecf** from (b)(i)]		1		1	1	
	(c)		R_{Tot} = 2 + 0.4 (**ecf**) (1) I = 1 [A] (**ecf**) (1)		1 1		2	2	
	(d)		At (0,0) there is no pd and no current (1) At (∞,6) as n becomes large 2 Ω becomes negligible (1) Therefore equivalent to emf i.e. $r\left(\frac{E}{r}\right)$ (1) Between (0,0) and (∞,6) 2 Ω becomes less and less significant so I increases (1)		1 1 1 1		4		
			Question 3 total	**3**	**7**	**0**	**10**	**3**	**0**

Question			Marking details	Marks available					
				AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
4	*(a)*		$C = \frac{\varepsilon_0 A}{d}$ used $\left(= \frac{8.85\text{x}10^{-12}\text{x}0.163}{0.35\text{x}10^{-3}} \right)$ (1) Answer = 4.12 nF **UNIT mark** (1)	1	 1		 2	 1	
	(b)	(i)	4.95 [μC] **ecf**		1		1		
		(ii)	2.97 [mJ] **ecf**		1		1	1	
	(c)		$Q = Q_0 e^{-\frac{t}{RC}}$ used **or** $T_{\frac{1}{2}} = RC \ln 2$ used (1) Logs taken correctly e.g. $\ln \frac{Q}{Q_0} = \frac{-t}{RC}$ **or** substitute into $T_{\frac{1}{2}} = RC \ln 2$ (1) Answer = 1.9 [ms] (1) **ecf**	1	 1 1		 3	 3	
	(d)		Shorter since energy proportional to Q^2		1		1		

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(e)*	(i)	 Correct circuit diagram e.g. as shown (1) Charging and discharging explained (1) e.g. switch left for charging, right for discharging Measure V at various (regular) time intervals (1) Use data logging because too quick for human (1)	1 1 1 1			4		4
		(ii)	Plot a graph of $\ln V$ against t (1) Should be a straight line (1) Negative gradient / gradient = $= \frac{-1}{RC}$ / positive intercept (1)		1 1 1		3		3
			Question 4 total	**6**	**9**	**0**	**15**	**5**	**7**

Question		Marking details	Marks available					
			AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*	Correct use of sin i.e. $\frac{r}{2} = 0.75\sin 10^\circ$ (1) So $r = 2\text{x}0.75\sin 10^\circ$ = 0.26 [m] (2nd mark implies first) (1)	1	1		2	2	
	(b)	$F = T\sin 10^\circ$ (1) also $mg = T\cos 10^\circ$ where $m = 5.0\times 10^{-3}$ kg (1) or equivalent Use of $F = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r^2}$ (1) $Q = \sqrt{4\pi\varepsilon_0 (0.26)^2 F}$ and comment (1)	1		1 1 1	4	4	
	(c)	Attempt at approximation of uncertainties (1) Obtaining uncertainties for all 3 measurements (1) Identification of source of largest uncertainty (i.e. the angle) (1) Therefore a suitable improvement suggested (1)			1 1 1 1	4		4
	(d)	Oscillation about equilibrium point **or** mid-point (1) Air resistance acts on balloons (1) [Heavily] damped oscillations **or** [over] damped SHM **or** critical damping (1)	1	1	1	3		
		Question 5 total	**3**	**2**	**8**	**13**	**6**	**4**

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
				Marks available					
6	*(a)*	(i)	$\frac{F}{m} = -\frac{GM}{r^2} = -5.90\times10^{-3}$ N kg^{-1} Use of formula (1) Answer + **UNIT** (1)	1	1		2	2	
		(ii)	$-\frac{GM}{r} = -8.85\times10^{8}$ [J kg^{-1}] Use of formula (1) Answer (1)	1	1		2	2	
	(b)		Good strategy chosen involving the use of Kepler's law (1) $\frac{T^2}{r^3} = \left[\frac{(3.16\text{x}10^7)^2}{(1.5\text{x}10^{11})^3}\right]$ = 2.96 × 10^{-19} Earth **and** $\frac{T^2}{r^3} = \left[\frac{(3.74\text{x}10^8)^2}{(7.79\text{x}10^{11})^3}\right]$ = 2.96 × 10^{-19} Jupiter calculated (1) **OR** $\frac{r^3}{T^2} = \left[\frac{(1.5\text{x}10^{11})^3}{(3.16\text{x}10^7)^2}\right]$ = 3.38 × 10^{18} Earth **and** $\frac{r^3}{T^2} = \left[\frac{(7.79\text{x}10^{11})^3}{(3.74\text{x}10^8)^2}\right]$ = 3.38 × 10^{18} Jupiter calculated Conclusion that the agreement is good / excellent [this must be consistent with the calculations shown] (1)		1	1 1	3	1	
			Question 6 total	**2**	**3**	**2**	**7**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*		Starting from $E = \frac{FL_0}{Ax}$ extension of bar of cross-sectional area $2A$ shown to be $\frac{F\frac{L_0}{2}}{2AE}$ **and** extension of bar of cross-sectional area A shown to be $\frac{F\frac{L_0}{2}}{AE}$ (1) Attempt at adding extensions made (1) Convincing algebra (1) e.g. common denominators shown: $\left[\frac{2FL_0}{4AE} + \frac{FL_0}{4AE}\right] = \frac{3FL_0}{4AE}$	1	1 1		3	3	3
	(b)	(i)	Line drawn correctly i.e. 2 × gradient/steepness as given line		1		1		1
		(ii)	Re-arrange for A bar, $2A$ bar or combination (1) Correct force-extension combination for each of above (1) Answer = 2 ×10^{11} [N m^{-2}] (1)		1	1 1	3	3	3
		(iii)	Use of $T = 2\pi\sqrt{\frac{m}{k}}$ (1) Gradient = $\frac{400}{8\text{x}10^{-6}}$ (1) Period = 4 m[s] (1)	1	1 1		3	3	3
			Question 7 total	**2**	**6**	**2**	**10**	**9**	**10**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*		Absorbs all radiation (don't accept 'all wavelengths') falling on it. Accept emits more radiation than any other body [at that temp] / perfect emitter / perfect absorber	1			1		
	(b)	(i)	$A = 4\pi \times (8.54 \times 10^8)^2$ **or** 9.16×10^{18} [m^2] (1) $P = 5.67 \times 10^{-8} \times$ area attempt $\times 5\,790^4$ (1) $P = 5.84 \times 10^{26}$ [W] with appropriate comment on consistency (1) [–1 for slips of 2^n, 10^n] Accept other alternatives e.g. finding P from A and T or finding A from P and T			1 1 1	3	3	
		(ii)	$\lambda_{max} = \frac{2.9\text{x}10^{-3}}{5790}$ **or** by implication (1) λ_{max} = 500 n[m] No **ecf** (1) Graph goes through origin with zero slope and acceptable at high λ (1) Peaks at approximately 500 nm **ecf** (1)	1	1 1 1		4	2	
			Question 8 total	**2**	**3**	**3**	**8**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	*(a)*	(i)	T = 1 090 × 24 × 60 × 60 = 9.42 × 10^7 [s] (1) Use of $r_S = \frac{Tv_S}{2\pi}$ or equivalent (1) = 6.82 × 10^8 [m] (1)		1 1 1		3	3	
		(ii)	Use of $d = \sqrt[3]{\frac{T^2 GM_S}{4\pi^2}}$ (1) Assumption $M_S >> M_P$ (1) = 3.21 × 10^{11} [m] (1)		1 1 1		3	3	
		(iii)	Use of $M_p = \frac{r}{r+d} M_s$ (1) = 4.7 × 10^{27} [kg] (1)	1	1		2	2	

Question			Marking details	Marks available					
				AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
9	*(b)*	(i)	Modern data has smaller random errors or points closer to the line of best fit (1) Modern data (or second graph) has no negative velocities (or blue shift) (1) Modern data is correct over a far larger range of distance (2 Mpc $\rightarrow$ 500 Mpc) (1) All of the above points can be made in reverse e.g. 1929 data is very noisy or 1929 data has data showing blue shift etc			1 1 1	3		3
		(ii)	Hubble's constant is the gradient (1) Answer = 64 [± 2] (1)			1 1	2	1	
		(iii)	Age of the universe = $\frac{1}{H_0}$ (1) Answer = 15.3 billion [years] (**ecf**) (1)	1	1		2	1	
			Question 9 total	**2**	**8**	**5**	**15**	**10**	**3**

COMPONENT 2: ELECTRICITY AND THE UNIVERSE

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	3	5	2	10	6	0
2	7	2	3	12	2	10
3	3	7	0	10	3	0
4	6	9	0	15	5	7
5	3	2	8	13	6	4
6	2	3	2	7	5	0
7	2	6	2	10	9	10
8	2	3	3	8	5	0
9	2	8	5	15	10	3
TOTAL	30	45	25	100	51	34