Capacitance - Mark Scheme

Q1.

Question Number	Answer		Mark
(a)	Use of $C = Q/V$ $Q = 1.0 \times 10^{-6}$ C <u>Example of calculation</u> $Q = 680 \times 10^{-9}$ F $\times$ 1.5 V $Q = 1.02 \times 10^{-6}$ C	(1) (1)	2
(b)	Use of $Q = Q_0\, e^{-t/RC}$ converts ms → **and** nF → F $Q = 1.3 \times 10^{-9}$ C (ecf their Q from (a)) Negligible charge **Or** fully discharged **Or** % charge remaining quoted correctly <u>Example of calculation</u> $Q = Q_0\, e^{-t/RC}$ $Q = (1.0 \times 10^{-6}\text{ C})\, e^{-0.001\text{s}/(220\,\Omega \times 680 \times 10^{-9}\text{ F})}$ $Q = 1.25 \times 10^{-9}$ C	(1) (1) (1) (1)	4
(c)	$I = fQ$ $I = 5.1 \times 10^{-4}$ A ecf their Q from (a) <u>Example of calculation</u> $I = fQ = 500\text{ Hz} \times 1.02 \times 10^{-6}$ C $I = 5.1 \times 10^{-4}$ A	(1) (1)	2
	Total for Question		**8**

Q2.

	Answer	Mark
	A	1

Q3.

Question Number	Answer	Mark
	D	1

Q4.

Question Number	Answer		Mark
(a)(i)	Use of $I = I_0 / e$ (I_0 from 2.35 mA to 2.4 mA) to find time constant **Or** intercept with t axis using initial tangent to find time constant (range 125 s to 135 s) Use of time constant = RC C = 0.015 (F) to 0.017 (F) **Or** Attempts a pair of readings of I and t from graph Use of $I = I_0 e^{-t/RC}$ C = 0.015 (F) to 0.017 (F) **Or** Attempts to obtain 'half-life' from graph Use of $t_{½} = RC \ln 2$ C = 0.015 (F) to 0.017 (F) <u>Example of calculation</u> 131 s = 8200 Ω × C $C = 1.60 \times 10^{-2}$ F	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**3**
(a)(ii)	Use of $V = IR$ for initial p.d. using initial current Use of $C = Q/V$ ecf from (i) Q = 0.32 C <u>Example of calculation</u> V = 0.0024 A × 8200 Ω = 19.7 V $\Delta Q = 1.60 \times 10^{-2}$ F × 19.7 V = 0.316 C	**(1)** **(1)** **(1)**	**3**
(a)(iii)	Use of suitable equation, e.g. $W = ½\, QV$ ecf from (i) and (ii) W = 3.1 J <u>Example of calculation</u> W = ½ × 0.316 C × 19.7 V W = 3.08 J	**(1)** **(1)**	**2**
(b)	Use of $V = V_0 e^{\frac{-t}{RC}}$ Correct use of 15% R = 240 kΩ <u>Example of calculation</u> $0.15 V_0 = V_0 e^{\frac{-t}{RC}}$ $\ln 0.15 + \ln V_0 = \ln V_0 - \frac{t}{RC}$ $\ln 0.15 = \frac{-210\ s}{R \times 470 \times 10^{-6}\ F}$ $R = 2.36 \times 10^{5}$ Ω	**(1)** **(1)** **(1)**	**3**
	Total for question		**11**

Q5.

Question Number	Answer		Mark
(a)	at least 3 horizontal straight lines touching both sides equispaced (by eye) arrow pointing to the right	(1) (1) (1)	**(3)**
(b)	Use of $W = \frac{1}{2}CV^2$ **Or** $Q = CV$ **and** $E = QV/2$ $W = 1.5 \times 10^{-10}$ J <u>Example of calculation</u> $W = ½ \times 12 \times 10^{-12}$ F $\times$ (5.0 V)^2 $W = 1.5 \times 10^{-10}$ J	(1) (1)	**(2)**
(c)	Use of $Q = CV$ Use of total charge before = total charge after **Or** Use of $Q_1 / Q_2 = C_1 / C_2$ (accept use of total capacitance = sum of capacitances) $V = 4.4$ V <u>Example of calculation</u> Total charge = 12×10^{-12} F $\times$ 5.0 V = 6.0×10^{-11} C 6.0×10^{-11} C = 12×10^{-12} F $\times V + 1.5 \times 10^{-12}$ F $\times V$ $V = 4.4$ V	(1) (1) (1)	**(3)**
	Total for question 12		**8**

Q6.

Question Number	Answer		Mark
(a)(i)	The idea that electrons move from one plate to the other plate through the external circuit When fully charged there is no movement of electrons **Or** As capacitor charges, rate of flow of electrons decreases **Or** (when fully charged) p.d. across the plates/capacitor is equal (and opposite) to the supply p.d. **Or** (when fully charged) equal and opposite charge/electrons on each plate	(1) (1)	**2**
(a)(ii)	Use of $W = \frac{1}{2} CV^2$ **Or** use of Q=CV **and** W=½QV W = 0.34 J Example of calculation $W = 0.5 \times 4700 \times 10^{-6}\text{F} \times (12\text{ V})^2 = 0.34\text{ J}$	(1) (1)	**2**
(b)(i)	Current decreases (over time) Exponentially (a graph of *I/t* with *I* decreasing can score MP1. Must be indicated as exponential for MP2)	(1) (1)	**2**
(b)(ii)	Use of $V = V_0 e^{-t/RC}$ **Or** see $\ln(V/V_0) = -t/RC$ Use V = 1.2 (V) **and** V_0 = 12(V) **Or** use $\frac{V}{V_0} = 0.1$ R = 2300 Ω Example of calculation $V = V_0 e^{-t/RC}$ $ln\left(\frac{V}{V_0}\right) = \frac{-t}{RC}$ $ln(0.1) = \frac{-25\text{ s}}{R \times 4700 \times 10^{-6}\text{ F}}$ $R = \frac{-25\text{ s}}{ln0.1 \times 4700 \times 10^{-6}\text{ F}}$ R = 2300 Ω	(1) (1) (1)	**3**
	Total for question		**9**

Q7.

Question Number	Answer	Mark
	B	1

Q8.

Question Number	Answer	Mark
	The only correct answer is B *A is not correct as this shows both charge and current decreasing, which would be correct for discharging but not charging.* *C is not correct as this shows both charge and current increasing, which is not possible in the circuit shown.* *D is not correct as this shows current increasing and charge decreasing, which is not possible in the circuit shown*	**(1)**

Q9.

Question Number	Answer		Mark
(a)	Use of $T = RC$ $T = 0.3$ s <u>Example of calculation</u> $T = RC = 1500\ \Omega \times 200 \times 10^{-6}$ F $T = 0.3$ s	(1) (1)	**2**
(b)	B5 = (6V - E4)/1.5 (k Ω) **Or** I = (E−V)/R **Or** I = (6.0 – 3.33)/1.5 Correct units or comment about mA and kΩ (allow 1 mark for B5 =C5/(A5-A4) and 1 mark for use of exponential equation)	(1) (1)	**2**
(c)(i)	3 points plotted accurately ± ½ small square Line of best fit drawn (smooth by eye)	(1) (1)	**2**
(c)(ii)	Initial tangent drawn $t = 0.19$ s –0.26 s **Or** 37% of initial current found $t = 0.24$ s –0.26 s **Or** half life determined and use of half life = 0.693RC $t = 0.23$ s –0.26 s **Or** uses a pair of points off the graph in exponential equation $t = 0.24$ s –0.26 s	(1) (1) (1) (1) (1) (1) (1) (1)	**2**
(c)(iii)	Reduce the time interval	(1)	**1**
***(d)**	Reference to $I = I_0 e^{-t/RC}$ **Or** $\ln I = \ln I_0 - t/RC$ **Or** states that there is exponential relationship between I and t Plot $\ln I$ against t **Or** $\ln (I/I_0)$ against t The time constant = −1/gradient	(1) (1) (1)	**3**
	Total for Question		**12**

Q10.

Question Number	Answer	Mark
	The only correct answer is A because **p.d. for each capacitor = $V/2$** **energy for each capacitor = ½ $C(V/2)^2 = CV^2/8$** **energy for pair of capacitors = $CV^2/4$** ***B*** *is not correct because this is the energy stored for a single capacitor with p.d. = V* ***C*** *is not correct because this is calculated without applying V/2* ***D*** *is not correct because this is 8 times the correct energy*	1