Capacitors MS2

Question Number	Answer		Mark
1(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**
1(a)(ii)	Use of $W = ½ CV^2$ **Or** use of Q=CV **and** W=½QV W = 0.34 J <u>Example of calculation</u> $W = 0.5 \times 4700 \times 10^{-6}\text{F} \times (12\text{ V})^2 = 0.34\text{ J}$	(1) (1)	**2**
1(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**
1(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 <u>Example of calculation</u> $V = V_0 e^{-t/RC}$ $ln\left(\frac{V}{V_0}\right) = \frac{-t}{RC}$ $ln(0.1) = \frac{-25\text{ s}}{R \times 4700 \times 10^{-6}\text{ F}}$ $R = \frac{-25\text{ s}}{ln0.1 \times 4700 \times 10^{-6}\text{ F}}$ R = 2300 Ω	(1) (1) (1)	**3**
	Total for question 1		**9**

Question Number	Answer		Mark
2(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**
2(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**
2(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**
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 2		**11**

Question Number	Answer	Mark
3(a)	Method marks only Use of Q=CV with V =16 V **(1)** Max value of C = 12000 (μF) **(1)** μF means 10^{-6} conversion of μF to F **(1)** <u>Example of calculation</u> C_{max} = 1.20 × 10000 = 12000 F C_{max} = 12000 F × 16 V Q_{max} = 0.192 C	**3**
3(b)	Either use of ½ QV or ½ CV^2 **(1)** Energy = 1.5 J **(1)** <u>Example of calculation</u> W = ½ 0.192 C × 16 V Energy = 1.54 J	**2**
	Total for question 3	**5**

Question Number	Answer		Mark
4(a)(i)	Use of $t=RC$ Use of $T=1/f$ **Or** $f = 1/t$ Comparison of 2.2×10^{-4} (s) << 2.5×10^{-3} (s) **Or** comparison of 400 (Hz)<< 4500 (Hz) **Or** reference to nRC (needed for complete discharge) where n = 3 – 11 **Or** $e^{-T/t}$ is a very small value	**(1)** **(1)** **(1)**	**3**
4(a)(ii)	See $C = Q/V$ **Or** $Q = CV$ See $Q = It$ See $t = 1/f$ **Or** $f = 1/t$ (Answers based on t = RC and V = IR scores 0)	**(1)** **(1)** **(1)**	**3**
4(a)(iii)	sub in $C = I/fV$ C = 2.7 μF <u>Example of calculation</u> $C = 5.4 \times 10^{-3}$ A/ (400 s^{-1} × 5.0 V) C = 2.7 μF	**(1)** **(1)**	**2**
4(a)(iv)	2.2 + 30% = 2.9 (μF) **Or** shows that 2.7 (uF) is +22% of 2.2 (uF) Within tolerance / consistent (2nd mark can only be awarded following an attempt at either of the above calculations) If candidates make an error in (iii) allow full ecf with a valid comment based on their values.	 **(1)** **(1)**	**2**
4(b)	Use of ½ CV^2 $W = 3.4 \times 10^{-5}$ J (allow ecf from (iii) or use of 2.2 μF→2.75×10^{-5} J) <u>Example of calculation</u> W = ½ 2.7 μF × $(5.0\ V)^2$ $W = 3.4 \times 10^{-5}$ J	**(1)** **(1)**	**2**
	Total for question 4		**12**

Question Number	Answer		Mark
5(a)(i)	(Capacitor) discharges **Or** loses charge **Or** p.d. across capacitor falls The idea that the discharge is not instantaneous [e.g., gradually, exponentially, over time]	**(1)** **(1)**	**2**
5(a)(ii)	Decay curve starting on *y* - axis but not touching *x* -axis. Initial current 2 mA Time axis labelled to indicate ($t_{1/2}$ =) 0.03 s **Or** Time axis labelled to indicate (RC =) 0.04 s **Or** Time axis labelled to indicate (5RC =) 0.2s	**(1)** **(1)** **(1)**	**3**
5(a)(iii)	Initially large current **Or** capacitor charges up Over a very short time **Or** happens instantaneously Because resistance is not in the charging circuit **Or** because $R = 0$	 **(1)** **(1)** **(1)**	**3**
5(b)	Use of $V = V_0 e^{-t/RC}$ with $V_0 = 20$V Correct conversion of both units $V = 0.13$ V <u>Example of calculation</u> $V = V_0 e^{-t/RC}$ $V = 20\ V\ e^{-0.20\ /\ 10\times10^3\times4\times10^{-6}}$ $V = 0.13$ V	**(1)** **(1)** **(1)**	**3**
5(c)	Use of $W = CV^2/2$ Use of $KE = mv^2/2$ $E_c/E_k = 0.023$ <u>Example of calculation</u> $E_C = CV^2/2 = 2600\ F \times (2.5\ V)^2 / 2 = 8125$ J $E_K = mv^2/2 = 800\ kg \times (30\ m\ s^{-1})^2 / 2 = 360\ 000$ J $E_C/E_k = 0.023$	**(1)** **(1)** **(1)**	**3**
	Total for question 5		**14**

Question Number	Answer	Mark
6(a)	Use of $C=Q/V$ **(1)** V= 15 V **(1)** Use of $W = QV/2$ **Or** $W = CV^2/2$ **Or** $W = Q^2/2C$ **(1)** $W = 2.5 \times 10^{-5}$ J **(1)** (candidates who use 6.6×10^{-6} C can only score MP1 and MP3) <u>Example of calculation</u> $V = Q/C = 3.3 \times 10^{-6}$ C / 220×10^{-9} F V= 15 V $W = QV/2 = (3.3 \times 10^{-6}$ C × 15 V)/2 $W = 2.5 \times 10^{-5}$ J	**4**
6(b)	$Q = 0.2\ Q_0$ **Or** $Q = 6.6\times 10^{-7}$ C **(1)** Use of $Q = Q_o\ e^{-t/RC}$ **(1)** t = 7.1 s **(1)** (candidates who use $Q = 0.8\ Q_0$ can only score MP2) <u>Example of calculation</u> $Q = 0.2\ Q_0$ $Q = Q_0\ e^{-t/RC}$ $0.2\ Q_0 = Q_0\ e^{-t/RC}$ $\ln(0.2) = -\ t/(20\times 10^6\ \Omega \times 220 \times 10^{-9}\ F)$ t = 7.1 s	**3**
6(c)	**Either** refers to $W = Q^2/2C$ **Or** $W \alpha Q^2$ **(1)** If Q halves, $W\rightarrow Q^2/8C$ Or halving Q quarters W **(1)** (Since W becomes a quarter in the time for Q to half) it takes less time for the energy to halve than the charge to halve. (dependent mark on either MP1 or MP2) **(1)** **Or** Refers to $W = QV/2$ **(1)** Q and V both decrease over time **(1)** W will decrease faster so takes less time to half in value. (dependent mark on either MP1 or MP2) **(1)**	**3**
6(d)	Synchronous readings **Or** data logger records readings at exact time **Or** voltmeter and stop watch need 2 people and data logger only one **(1)** More readings can be taken in a shorter time **Or** higher sampling rate **(1)** (treat as neutral any reference to graph plotting automatically, human reaction time or accuracy)	**2**
	Total for question 6	**12**

Question Number	Answer		Mark
7(a)	Use of $C = Q/V$ $Q = 1.0 \times 10^{-6}$ C <u>Example of calculation</u> $Q = 680 \times 10^{-9}$ F × 1.5 V $Q = 1.02 \times 10^{-6}$ C	**(1)** **(1)**	**2**
7(b)	Use of $Q = Q_o\, e^{-t/RC}$ 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> $Q = Q_o\, e^{-t/RC}$ $Q = (1.0 \times 10^{-6}\text{ C})\, e^{-0.001\text{s}/(220\,\Omega \times 680 \times 10^{-9}\text{ F})}$ $Q = 1.25 \times 10^{-9}$ C	**(1)** **(1)** **(1)** **(1)**	**4**
7(c)	$I = fQ$ $I = 5.1 \times 10^{-4}$ A ecf their Q from (a) <u>Example of calculation</u> $I = fQ$ = 500 Hz × 1.02×10^{-6} C $I = 5.1 \times 10^{-4}$ A	**(1)** **(1)**	**2**
	Total for Question 7		**8**

Question Number	Answer	Mark
8*(a)	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Between the plates there is a force (references to repulsion and attraction are not sufficient) **(1)** Gives a downward acceleration **Or** accelerates towards the negative plate **(1)** Constant horizontal velocity **Or** no forces act horizontally **(1)** Outside the plates no (electric) field /force acts **Or** Outside the plates speed so large that gravitational effect negligible **(1)**	**4**
8(b)(i)	Magnetic force = electric force **Or** $Eq = Bqv$ **(1)** Forces must act in opposite directions **Or** resultant force is zero. **Or** (magnetic) field into page **(1)** (do not credit if forces stated as being perpendicular to each other)	**2**
8(b)(ii)	Use of $E = V/d$ **(1)** Evidence of equating two forces $Bqv = Eq$ (award if you see $Bv = E$) **(1)** Both unit conversions correct. **(1)** $B = 5.1 \times 10^{-3}$ T **(1)** (There is no credit for alternative methods where assumptions have to be made about value of charge and /or mass) <u>Example of calculation</u> $E = V/d$ $Bqv = Eq$ $B = E/v = V/dv$ $B = 60 \text{ V} / (4.5 \times 10^{-2} \text{ m} \times 260 \times 10^{3} \text{ m s}^{-1})$ $B = 5.1 \times 10^{-3}$ T	**4**
8(c)	Upward path (not downwards) **Or** magnetic path is arc of a circle **(1)** Magnetic force changes direction as ions path changes **Or** magnetic force perpendicular to path/velocity of ion. **(1)** Electric force constant direction **Or** electric force always acts downwards. **Or** electric path is parabolic **(1)**	**3**
	Total for Question 8	**13**