Mark Scheme

Q1.

Question Number	Acceptable answers	Additional guidance	Mark
	D uses $W = \frac{1}{2}CV^2$ so if V is doubled W is 4×	$4W$	**1**
	A divides the energy by 4 (rather than multiply) B forgets to square the potential difference and divides C forgets to square the potential difference		

Q2.

Question Number	Answer	Mark
	B	1

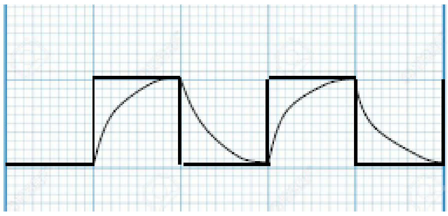
Q3.

Question Number	Answer	Mark
	B	**1**

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• p.d. across capacitor increases **Or** p.d. across resistor decreases (1) • p.d. across capacitor increases to 5V (1) • p.d. across resistor starts at 5V and reduces to 0V (1) • Exponentially (1)		**4**

Q5.

Question Number	Acceptable answers		Additional guidance	Mark
	• Time axis: one cycle = 50 OR two cycles =100 • Use of time constant = *RC* • Charging curve, from 25 ms to 50 ms, just about reaching 5V as shown (ecf from their T) • One corresponding discharge curve • Curve should look exponential	(1) (1) (1) (1) (1)	<u>Example of calculation</u> $T = 1/f = 1/20\text{ Hz} = 0.050\text{ s}$ Two cycles $= 2 \times 0.050\text{ s} = 0.10\text{ s} = 100\text{ ms}$ Time Constant $= 100 \times 50 \times 10^{-6} = 0.005\text{ s}$ In half a cycle (0.025 s) there are 0.025 s / 0.005 s = 5 Time constants Ignore anything drawn in the first half cycle  Time period should be marked 50 ms or equivalent	5

Q6.

Question Marks	Acceptable Answers		Additional guidance	Mark
i	• Use of $W = \frac{1}{2}CV^2$ • $W =$ 45 μJ	(1) (1)	Example of calculation $W = \frac{1}{2} 40\mu F \times (1.5\ V)^2$ $W =$ 45 μJ Alt: Use $Q = CV$ then $E = QV/2$ for MP1	2
ii	• Use of $V = V_o e^{-t/RC}$ • Time = 0.14 (s)	(1) (1)	Example of calculation $0.5 = e^{-t/5000 \times 40 \times 10^{-6}}$ $\ln 0.5 = -t/0.2$ $t = 0.14$s	2
iii	• Use of speed = d/t • Speed = 3.6 ms^{-1} Allow ecf from ii	(1) (1)	Show that value gives 5.0 ms^{-1} Example of calculation $v = 0.5m/0.14s$ $= 3.6\ ms^{-1}$	2
iv	• use of $s = \frac{at^2}{2}$ • s = 9 cm + comment that foil is not broken at its centre (comment consistent with calculation) Allow ecf from ii	(1) (1)	Show that value gives 0.049 m Example of calculation $s = \frac{9.81\ ms^{-2} \times 0.14^2\ s}{2} = 0.094$ m	2

Q7.

Question Number	Answer		Mark
(a)	Use of $Q = CV$ $Q = 0.18$ C <u>Example of calculation</u> $Q = 150 \times 10^{-6}$ F $\times$ 1200 V $Q = 0.18$ C	**(1)** **(1)**	**2**
(b)	Use of $W = \frac{1}{2} CV^2$ **Or** of $W = \frac{1}{2} QV$ **Or** of $W = \frac{1}{2} Q^2/C$ $W = 110$ J Allow ecf from (a) if $\frac{1}{2} QV$ or $\frac{1}{2} Q^2/C$ used <u>Example of calculation</u> $W = \frac{1}{2} \times 150 \times 10^{-6}$ F $\times$ (1200 V)^2 $W = 108$ J	**(1)** **(1)**	**2**
(c)(i)	$R = 86$ (Ω) <u>Example of calculation</u> $R = V/I$ = 1200 V / 14 A $R = 85.7$ Ω	**(1)**	**1**
(c)(ii)	$Q = 0.25\ Q_0$ **Or** $Q = 0.045$ C Use of RC (0.013 s) Use of $Q = Q_0\ e^{-t/RC}$ to give $t = 0.018$ s (show that value will give $t = 0.019$ s) [Use of ln 4 gives the correct answer if the − sign is ignored , scores 1 for use of RC use of ¾Q →3.7 × 10^{-3} s scores 1 mark] **Or** Use of RC Use of 2 × 0.69 × RC $t = 0.018$ s <u>Example of calculation</u> $Q = 0.25\ Q_0$ $Q = Q_0\ e^{-t/RC}$ $0.25\ Q_0 = Q_0\ e^{-t/RC}$ ln (0.25) = - t/ (86 Ω × 150 × 10^{-6} F) $t = 0.0178$ s	**(1)** **(1)** **(1)**	**3**
(c)(iii)	Same charge (flows for shorter time) **OR** (Same charge flows for) shorter time	**(1)**	**1**

Q8.

Question Number	Answer		Mark
(a)	Use of $Q = It$ $Q = 2.8$ C <u>Example of calculation</u> $Q = 2.0 \times 10^3$ A $\times 1.4 \times 10^{-3}$ s $Q = 2.8$ C	**(1)** **(1)**	**2**
(a)(ii)	See $\tau = RC$ $\tau = 3.0 \times 10^{-4}$ (s) Relates time constant to the time for which current is required <u>Example of calculation</u> $\tau = 0.50\Omega \times (600 \times 10^{-6}$ F) $\tau = 3.0 \times 10^{-4}$ s 1.4×10^{-3}s / 3.0×10^{-4} s = 4.7RC	**(1)** **(1)** **(1)**	**3**
(b)(i)	Use of $Q = CV$ $V = 4700$ V (e.c.f from (a)(i)) <u>Example of calculation</u> $V = 2.8$V / $(600 \times 10^{-6}$ F) $V = 4670$ V	**(1)** **(1)**	**2**
(b)(ii)	Use of $W = ½\, QV$ **Or** $W = ½\, Q^2/C$ **Or** $W = ½\, CV^2$ Use of $P = W/t$ $P = 4.7$ MW (e.c.f. from (a)(i) and/or (b)(i)) <u>Example of calculation</u> $P = (2.8$ C $\times 2.8$ C) / (2 $\times$ 600 $\times 10^{-6}$ F $\times 1.4 \times 10^{-3}$ s) $P = 4.7$ MW	**(1)** **(1)** **(1)**	**3**
	Total for question		**10**

Q9.

Question Number	Answer		Mark
(a)(i)	Capacitor, resistor, supply and switch all in series (ignore voltmeter) Voltmeter directly across capacitor	**(1)** **(1)**	**2**
(a)(ii)	Datalogger allows large number of readings to be taken **Or** graph can be plotted directly/automatically **Or** simultaneous reading of t and V can be taken **Or** idea that people can't record quickly enough, (treat as neutral accuracy, precision misreading or human reaction time)	**(1)**	**1**
(b)	Use of $C = Q/V$ $Q = 5.0 \times 10^{-4}$ C <u>Example of calculation</u> $Q = 100 \times 10^{-6}$ F $\times$ 5.0 V $Q = 5.0 \times 10^{-4}$ C	**(1)** **(1)**	**2**
(c)(i)	Use of $I = \Delta Q/\Delta t$ e.c.f their value of C from (b) $I = 0.05$ A (accept recalculation of Q using $V = 4.90$ or 4.95 V) <u>Example of calculation</u> $I = 5.0 \times 10^{-4}$ C / 10×10^{-3} s $I = 0.05$ A	**(1)** **(1)**	**2**
(c)(ii)	tangent drawn at t = 0 $\Delta V/\Delta t$ = 2000 - 3300 V s^{-1} Initial current = 0.22 - 0.28 A (MP2 & 3 can be scored even if no tangent drawn) (No credit for exponential calculation) <u>Example of calculation</u> $\Delta V/\Delta t$ = 1.1 V/ 0.5 ms = 2200 V s^{-1} $I = (\Delta V/\Delta t) \times C$ I = 2200 V s^{-1} $\times$ 100 $\times$ 10^{-6} F $I = 0.22$ A	**(1)** **(1)** **(1)**	**3**
(c)(iii)	Use of $V = IR$ using answer from (ii) correct evaluation of R (5V used with current range in (ii) gives 18 - 23 Ω) <u>Example of calculation</u> 5 V = 0.22 A $\times$ R R = 23 Ω	**(1)** **(1)**	**2**
	Total for question		**12**

Q10.

Question Number	Answer		Mark
(a)	Use of $C=Q/V$ $V = 15$ V Use of $W = QV/2$ **Or** $W = CV^2/2$ **Or** $W = Q^2/2C$ $W = 2.5 \times 10^{-5}$ J (candidates who use 6.6×10^{-6} C can only score MP1 and MP3) Example of calculation $V = Q/C = 3.3 \times 10^{-6}$ C / 220×10^{-9} F $V = 15$ V $W = QV/2 = (3.3 \times 10^{-6}$ C $\times$ 15 V)/2 $W = 2.5 \times 10^{-5}$ J	(1) (1) (1) (1)	4
(b)	$Q = 0.2\ Q_0$ **Or** $Q = 6.6\times 10^{-7}$ C Use of $Q = Q_o\ e^{-t/RC}$ $t = 7.1$ s (candidates who use $Q = 0.8\ Q_0$ can only score MP2) Example of calculation $Q = 0.2\ Q_0$ $Q = Q_0\ e^{-t/RC}$ $0.2\ Q_0 = Q_0\ e^{-t/RC}$ ln (0.2) = - t/ ($20\times 10^6\ \Omega \times 220 \times 10^{-9}$ F) $t = 7.1$ s	(1) (1) (1)	3

(c)	**Either** refers to $W = Q^2/2C$ **Or** $W \alpha Q^2$ If Q halves, $W \rightarrow Q^2/8C$ Or halving Q quarters W (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) **Or** Refers to $W = QV/2$ Q and V both decrease over time W will decrease faster so takes less time to half in value. (dependent mark on either MP1 or MP2)	 (1) (1) (1) (1) (1) (1)	3
(d)	Synchronous readings **Or** data logger records readings at exact time **Or** voltmeter and stop watch need 2 people and data logger only one More readings can be taken in a shorter time **Or** higher sampling rate (treat as neutral any reference to graph plotting automatically, human reaction time or accuracy)	(1) (1)	2
	Total for question		**12**

Q11.

Question Number	Answer		Mark
(a)	The capacitor stores charge **Or** capacitor charges from the supply The idea that the capacitor doesn't fully discharge before being recharged.	(1) (1)	2
(b)(i)	$(6.4 + 4.4)/2 = 5.4$ V	(1)	1
(b)(ii)	Use of $V = IR$ Average $I = 5.4$ V/($2.2 \times 10^3\Omega$) = 2.5×10^{-3} A ecf value form (b)(i)	(1) (1)	2
(b)(iii)	Time = 17 ms or 17.5 ms	(1)	1
(b)(iv)	Use of $Q = It$ Use of $C = Q/V$ Use of $\Delta V = 2.0$ V $C = 21$ μF (ecf values of I and t from above) <u>Example of calculation</u> $Q = 2.5 \times 10^{-3}$ A $\times 17 \times 10^{-3}$ s $= 4.25 \times 10^{-5}$ C $C = 4.25 \times 10^{-5}$ C / 2.0 V $C = 21$ μF	(1) (1) (1) (1)	4
(c)	Uses a larger capacitance Because a larger time constant is needed **Or** stores more charge **Or** less $\Delta V \rightarrow \Delta Q/C$	(1) (1)	2
	Total for question		12

Q12.

Question Number	Answer		Mark
(a)(i)	Use of $Q = CV$ Q = 3900 (C) Example of answer Q = 1500 F × 2.6 V Q = 3900 C	(1) (1)	2
(a)(ii)	Straight line through the origin Passing through 2.6 V and answer to (a)(i) or 4000 C	(1) (1)	2
(a)(iii)	Use of $W = QV/2$ **Or** $W = CV^2/2$ **Or** use of area under graph W = 5.1 kJ (use of 4000 C gives W = 5.2 kJ (allow ecf from (a)(i)) Example of answer W = 3900 C × 2.6 V / 2 W = 5070 J	(1) (1)	2
(b)(i)	Exponential decay Current decreases by equal fractions in equal time intervals	(1) (1)	2
(b)(ii)	See attempt of I_0/e Finds time (accept 0.75-0.80s) Use of $\tau = RC$ R = 0.0005 Ω **Or** Finds the time for I_o to half Uses $t_{1/2} = \tau \ln 2$ Use of $\tau = RC$ R = 0.00050 – 0.00053 Ω **Or**	(1) (1) (1) (1) (1) (1) (1) (1)	
	See attempt of 37% of 5400 A Finds time (accept 0.75 to 0.80 s) Use of $\tau = RC$ R = 0.0005 – 0.00053Ω **Or** Draws tangent at t = 0 to meet time axis. Records intercept of tangent with axis (accept 0.6 s - 0.9 s) Use of $\tau = RC$ R = 0.0004 Ω – 0.0006 Ω **Or** reads a value off the y-axis and corresponding time Subs into formula using 5400 (A) to find RC Substitutes for C to find R R = 0.00050 Ω – 0.00058 Ω Example of calculation 37% of 5400 A is 1998 A Time to fall to this value is 0.75 s RC = 0.75 s R =0.75 s / 1500 F = 0.0005 Ω	(1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	4

(c)	**Max 3** Ultracapacitor used for: overtaking **Or** going up a hill **Or** starting (from rest) **Or** accelerating. (1) Because this requires a large current/power. (1) Batteries used for travelling at constant speed (1) Because this requires a small current/power for a longer time (1)	3
	Total for question	**15**