Question			Answer	Marks	Guidance
1	(a)	(i)	Correct shape of (exponential) decay curve (labelled **L**)	B1	**Note**: The curve must show a gradient of decreasing magnitude as time increases and appear to have a finite value of V at $t = 0$ **Ignore** any levelling of the curve or $V = 0$ towards the end
		(ii)	Correct shape of curve (labelled **H**)	B1	**Note**: As **(i)** and this curve must show a smaller time constant than **(i)**; the initial V can be different **Note**: One of the curves must be labelled
		(iii)	Correct explanation in terms of constant-ratio for V values for <u>fixed</u> intervals of t	B1	**Allow** V is halved every half-life; V decreases to 0.37 (of its initial value) after every time constant **Note**: This can be scored on a suitably labelled sketch graph in either **(iii)** or Fig. 4.1
	(b)	(i)	(time constant = $6.9 \times 10^{-6} \times 240$) time constant = 1.7×10^{-3} (s)	B1	**Note**: Answer to 3 sf 1.66×10^{-3} (s)
		(ii)	charge = $6.9 \times 10^{-6} \times 1.4$ (= 9.66×10^{-6} C) (Δt = 1/120 = 0.0083 s) current = $\dfrac{6.9\times10^{-6}\times1.4}{0.0083}$ current = 1.2×10^{-3} (A)	C1 C1 A1	Possible ecf from **(b)(i)** for value of total capacitance **Note**: Answer to 3 sf 1.16×10^{-3} (A) **Allow**: 2 marks for $9.66 \times 10^{-6} \times 60 = 5.8 \times 10^{-4}$ (A); Δt = 1/60 s used **Allow**: 2 marks for $9.66 \times 10^{-6} \times 240 = 2.3 \times 10^{-3}$ (A); Δt = 1/240 s used
		(iii)	The capacitors do not fully discharge (AW) Any <u>one</u> from: • Period (of switching) is (halved to) 4.2×10^{-3} (s) (and this time is comparable to the time constant) • The time constant (of the circuit) and period of mechanical switch are comparable / similar	B1 B1	
			Total	**9**	

Question			Answers	Marks	Guidance
2	(a)		The time taken for the p.d / current / charge to decrease to $1/e$ of its (initial) value.	B1	**Allow** 37% instead of $1/e$. **Not** time constant = CR on its own.
	(b)		Any suitable values with units, eg: 5 MΩ and 1 μF.	B1	
	(c)	(i)	$R = \dfrac{4.9\times10^{-7}\times5.0}{\pi\times(0.06\times10^{-3})^2}$ or R = 217 (Ω) time constant = 0.010 × 217 time constant = 2.2 (s)	C1 C1 A1	**Note**: An incorrect equation here for A prevents this and any subsequent marks. **Allow** 2 marks for 0.54 (s) – diameter of 0.12 mm used instead of radius 0.06 mm.
		(ii)	Electrons are removed from **X** or electrons are deposited on **Y**. **X** becomes positive or **Y** becomes negative (The size of charge is the same because) an equal number of electrons are removed and deposited (on the plates).	B1 B1 B1	**Allow** electrons move anticlockwise (in the circuit). There is no ecf from the previous B1 mark.
		(iii)	$E = \frac{1}{2} \times 0.010 \times 12^2$ or E = 0.72 (J) $m = 8900 \times [\pi \times (0.06 \times 10^{-3})^2 \times 5.0]$ or $5.0(3) \times 10^{-4}$ (kg) $5.03 \times 10^{-4} \times 420 \times \Delta\theta = 0.72$ increase in temperature = 3.4 (°C)	C1 C1 C1 A1	**Note**: An incorrect equation here for m or V prevents this and any subsequent marks. Correct substitution into $mc\Delta\theta = 0.72$; **allow** any subject. **Note**: Do not penalise using diameter here again if already penalised in **(c)(i)**.
		(iv)	Energy or V^2 increases by a factor of 4. The (change in temperature) increases by a factor of 4 (because $\Delta\theta \propto E$).	B1 B1	**Allow** the label E or W for energy. **Allow** $\Delta\theta$ = 13.6 (°C) for this B1 mark - possible ecf from **(iii)**.
			Total	**14**	

Question			Answer	Marks	Guidance
3	(a)		Series branch: Using $(100^{-1} + 300^{-1})^{-1}$ and C = 75 (μF) capacitance = 500 + 75 capacitance = 575 (μF)	C1 A1	 Possible ecf, if capacitance of series branch is incorrect
	(b)	(i)	**Time constant method:** 37% of 6.0 V is 2.2 V. The time taken to reach 2.2 V is equal to the time constant time constant = 60 (s) / CR = 60 (s) $500 \times 10^{-6} \times R = 60$ $R = \frac{60}{500 \times 10^{-6}}$ resistance = 1.2×10^{5} (Ω) **Substitution method:** Correct values for p.ds and t substituted into $V = V_0 e^{-\frac{t}{CR}}$ Correct values substituted into $\ln(V/V_0) = -\frac{t}{CR}$ resistance = 1.2×10^{5} (Ω)	 C1 C1 A1 C1 C1 A1	**Note**: Allow full credit for other correct methods **Allow**: time constant in the range 58 s to 62 s Deduct 1 mark for misreading graph followed by ecf **Note**: If C value from **(a)** is used, then deduct 1 mark followed by ecf **Eg**: $2.2 = 6.0e^{-\frac{60}{CR}}$ - values read t ± 1 small square **Eg:** $\ln(2.2/6.0) = -\frac{60}{500 \times 10^{-6} \times R}$ **Note**: If C value from **(a)** is used, then deduct 1 mark followed by ecf. Using 575 (μF) gives 1.04×10^{5} (Ω)
		(ii)	Correct p.ds from graph: 6 (V) and 3.6 (V) $\frac{1}{2} \times 500 \times 10^{-6} \times 6.0^{2}$ or $\frac{1}{2} \times 500 \times 10^{-6} \times 3.6^{2}$ energy is 9.00×10^{-3} (J) and 3.24×10^{-3} (J) energy lost = 5.76×10^{-3} (J) or 5.8×10^{-3} (J)	C1 C1 A1	**Allow** V value to be in the range 3.5 V to 3.7 at 30s **Note**: Do not penalise 10^{n} error from **(b)(ii)** again here **Allow** 1 mark for: $\frac{1}{2} \times 500 \times 10^{-6} \times (6.0 - 3.6)^{2} = 1.44 \times 10^{-3}$ (J) **Note**: Do not penalise use of 575 μF again. This gives a value of 6.62×10^{-3} (J)
			Total	**8**	

Question			Answer	Marks	Guidance
4	(a)		(farad = 1) coulomb per (unit) volt	B1	**Allow**: C V^{-1}
	(b)	(i)	1/C	B1	**Allow**: 'inverse of *C*'
		(ii)	work (done) / energy	B1	
	(c)		**Diagram**: All 3 capacitors connected in **series** $\frac{1}{C} = \frac{1}{100} + \frac{1}{200} + \frac{1}{500}$ / $\frac{1}{C} = 1.7 \times 10^{-2}$ capacitance = 59 (μF)	B1 C1 A1	**Note**: Correct symbol must be used for capacitor and at least one of the capacitance values (without the unit) must be shown **Allow**: Answer to 1 sf **Note**: Answer to 3sf is 58.8 (μF) **Allow**: 1.7×10^{-2} (μF) scores 1 mark from the C1A1
	(d)	(i)	$Q = 0.040 \times 60$ charge = 2.4 (C)	C1 A1	 **Allow**: 1 mark for 2.4×10^{n}, $n \neq 0$ (POT error)
		(ii)	energy = $\frac{1}{2} \times \frac{2.4^2}{0.10}$ energy = 29 (J)	C1 A1	Possible ecf from **(d)(i)** **Note**: Answer to 3 sf is 28.8 (J) Allow full credit for correct use of ½ VQ or ½ V^2C; the final p.d is 24 (V)
			Total	**10**	

Question			Expected Answers	Marks	Additional guidance
5	**(a)**		capacitance = charge / potential difference	B1	**Allow:** p.d. and voltage **Not:** charge per volt or coulombs per p.d
	(b)	**(i)**	$V = Q/C$ and Q = constant in series circuit $V = \frac{450}{450+150} \times 6.0$ potential difference = 4.5 (V)	C1 A1	**Allow:** 1 mark for an answer of 1.5 (V) **Note**: Using **(b)(ii)**, alternative marking scheme $V = 6.75 \times 10^{-4}/150 \times 10^{-6}$ C1 $V = 4.5$ V A1
		(ii)	charge = $150 \times 10^{-6} \times 4.5$ charge = 6.75×10^{-4} (C)	B1	Possible e.c.f. **Note**: Using **(b)(iii)** ... $Q = 6.0 \times 1.125 \times 10^{-4} = 6.75 \times 10^{-4}$ (C)
		(iii)	$\frac{1}{C} = \frac{1}{150} + \frac{1}{450}$ (working in μF) capacitance $C_T = 1.125 \times 10^{-4}$ (F) or 113 μ(F)	B1	**Possible alternative:** capacitance = $6.75 \times 10^{-4}/6.0$ capacitance = 1.125×10^{-4} (F) or 113 μ(F) Possible e.c.f. from **(ii)**
	(c)	**(i)**	time constant = CR time constant = $1.125 \times 10^{-4} \times 45 \times 10^{3}$ time constant = 5.06 (s)	M1 A0	**Note:** The mark is for multiplying correct C and R values Possible e.c.f. from**(b)(iii)**
		(ii)	Graph starting from 6.0 (V) Correct shaped curve Approximately correct value of V at CR	B1 B1 B1	 **Note:** The (exponential decay) curve must not touch or cut the time axis **Note:** V is 2 to 2.5 (V) at $t \approx 5$ s

Question			Expected Answers	Marks	Additional guidance
		(iii)	$\frac{1}{2}\times 4.5^2 \times 150\times 10^{-6}$ <u>and</u> $\frac{1}{2}\times 1.5^2 \times 450\times 10^{-6}$ ratio = $\dfrac{0.5\times 4.5^2 \times 150\times 10^{-6}}{0.5\times 1.5^2 \times 450\times 10^{-6}}$ ratio = 3 Or ½ Q^2/C_{150} and ½ Q^2/C_{450} ratio = C_{450} / C_{150} ratio = 3	C1 A1 C1 A1	**Allow:** with or without the 10^{-6} Possible e.c.f. from **(b)(i)** and **(b)(ii)** **Allow:** full credit for correct use of either ½QV or ½ Q^2/C
		(iv)	The ratio remains constant The charge / Q is the same for both capacitors	B1 B1	
			Total	**13**	