Answers – Mixed Exam Questions – Set 9

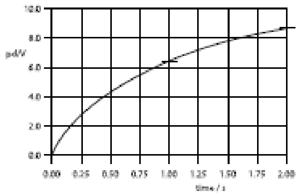
1.

Question	Answers	Additional Comments/Guidance	Mark
(a)(i)	determine area under the graph [**or** determine area between line and time axis] ✓		1
(a)(ii) *as seen*	line starts at very low current (within bottom half of first square) ✓ **either** line continuing as (almost) horizontal straight line to end ✓✓ **or** very slight exponential decay curve ✓ which does not meet time axis ✓ **OR** suitable verbal comment that shows appreciation of difficulty of representing this line on the scales involved ✓✓✓	*Use this scheme for answers which treat the information in the question literally.*	3
(a)(ii) *as intended*	line starts at half of original initial current ✓ slower discharging exponential (ie. smaller initial gradient) than the original curve ✓ correct line that intersects the original curve (**or** meets it at the end) ✓	*Use this scheme for answers which assume that both resistance values should be in Ω or kΩ.* ½ initial current to be marked within ±2mm of expected value.	3
(b)(i)	energy stored (= ½ CV^2) = ½ × 0.12 × 9.0^2 ✓ (= 4.86 (J)) 4.86 = 3.5 Δh ✓ gives Δh = (1.39) = 1.4 (m) ✓ to 2SF only ✓	SF mark is independent. Students who make a PE in the 1st mark may still be awarded the remaining marks: treat as ECF.	4
(b)(ii)	energy is lost through heating of wires **or** heating the motor (as capacitor discharges) ✓ energy is lost in overcoming frictional forces in the motor (or in other rotating parts) ✓ [**or** any other well-expressed sensible reason that is valid eg. capacitor will not drive motor when voltage becomes low ✓]	Allow heating of circuit **or** I^2R heating. Location of energy loss (wires, or motor, etc) should be indicated in each correct answer. Don't allow losses due to sound, air resistance or resistance (rather than heating of) wires.	max 2

2.

a	i	$Q(=It) = 4.5\times10^{-6}\times60$ **or** $= 2.70\times10^{-4}$ (C) ✓ $C\left(=\frac{Q}{V}\right)=\frac{2.70\times10^{-4}}{4.4}$ ✓ $= 6.1(4)\times10^{-5}$ $= 61$ (μF) ✓	3	
a	ii	since V_C was 4.4V after 60s, when t = 30s V_C = 2.2 (V) ✓ [**or** by use of $Q = It$ and $V_C = Q/C$] ∴ pd across R is (6.0 – 2.2) = 3.8 (V) ✓ $R\left(=\frac{V}{I}\right)=\frac{3.8}{4.5\times10^{-6}}$ $= 8.4(4)\times10^{5}$ (Ω) ✓ (=844 kΩ)	3	In alternative method, $Q = 4.5\times10^{-6}\times30 = 1.35\times10^{-4}$ (C) $V_C = 1.35\times10^{-4} / 6.14\times10^{-5} = 2.2$ (V) (allow ECF from wrong values in (a)(i))
		Charging • electrons flow from plate **P** to terminal **A** and from terminal **B** to plate **Q** (ie. from plate **P** to plate **Q** via **A** and **B**) • electrons flow in the opposite direction to current • plate **P** becomes + and plate **Q** becomes – • the rate of flow of electrons is greatest at the start, and decreases to zero when the capacitor is fully charged • V_R decreases from E to zero whilst V_C increases from zero to E. • at any time $V_R + V_C = E$ • time variations are exponential decrease for V_R and exponential increase for V_C • chemical energy of the battery is changed into electric potential energy stored in the capacitor, and into thermal energy by the resistor (which passes to the surroundings) • half of the energy supplied by the battery is converted into thermal energy and half is stored in the capacitor		
		Discharging • electrons flow back from plate **Q** via the shorting wire to plate **P** • at the end of the process the plates are uncharged • the rate of flow of electrons is greatest at the start, and decreases to zero when the capacitor is fully discharged • V_C decreases from $-E$ to zero and V_R decreases from E to zero • at any time $V_C = -V_R$ • both V_C and V_R decrease exponentially with time • electrical energy stored by the capacitor is all converted to thermal energy by the resistor as the electrons flow through it and this energy passes to the surroundings • time constant of the circuit is the same for discharging as for charging		

3.

03.1	(refers to a capacitor that) stores/holds/changes by 370 μC of charge ✓ for every (1) volt/volt change (of pd across its plates) ✓ **OR** reference to charge to pd OR charge to voltage ratio✓ includes units C or coulomb and V or volt ✓	"Unit of pd" is no substitute for using volt and "unit of charge" is no substitute for coulomb. However the alternative marking could give a single mark for 370×10^{-6} units of charge per unit of pd. An equation may contribute towards the first mark but only if the symbols are identified. A second mark can be given if the units are identified. Ignore poor phrasing like 'per unit volt passing through'.	2	AO1
03.2	(Using time constant = RC) ($R = 1.0 / 370 \times 10^{-6}$) $R = 2.7 \times 10^{3}$ (Ω) ✓	Check that the unit on answer line has not been altered	1	AO1
03.3	First mark for marking a cross at 2 s and 8.5 V (by eye) ✓ Second mark for graph starting at the origin and having a decreasing gradient ie not reaching horizontal ✓ 	Cross must be in the bottom half but not on the 8.0 V major grid line or exactly half way up (9.0 V) If a series of plotting crosses are given only consider the one placed at 2 s for the first mark.	2	AO2

03.4	(Using $T_{½} = 0.69\ RC = 0.69 \times 1.0$) $T_{½} = 0.69$ (s) ✓	1 sig fig is not acceptable	1	AO1
03.5	(Use of $Q = Q_o(1 - e^{-\frac{t}{RC}}) = CV_o(1 - e^{-\frac{t}{RC}})$) mark for max charge = CV_o which may come from substitution or seeing $3.6(2) \times 10^{-3}$ C ✓ $3.0 \times 10^{-3} = 370 \times 10^{-6} \times 9.8\ (1 - e^{-t})$ ✓ mark for substitution ($0.8274 = (1 - e^{-t})$ so $e^{t} = 1/0.173 = 5.79$) $t = 1.7$ s or 1.8 s ✓ **OR** voltage $V = Q/C = 3 \times 10^{-3} / 370 \times 10^{-6}$ $= 8.1(1)$ V✓ (Substitute into $V = V_o(1 - e^{-\frac{t}{RC}})$) $8.1 = 9.8\ (1 - e^{-t})$ ✓ $t = 1.7$ s or 1.8 s ✓	Alternative mark scheme uses the voltage as proportional to the charge. Do not allow use of the graph for 2nd mark and 3rd mark. An answer only gains only the last mark. Evidence of working must be shown which shows substitution into a ($1\text{-}e^{-t}$) form of the equation.	3	AO2

4.

a		Capacitance = charge per (unit) potential difference	**B1**	Allow: capacitance = charge / potential difference, charge/pd, charge/voltage but not charge / volt, coulomb /pd (no mixture of quantities and units. Allow 'over' instead of per
b	**(i)**	Q = CV = 4.5 μ x 6.3 = 28.(35) (μC)	**B1**	Allow: 28 (≥ 2 sf)
	(ii)	$E = ½ CV^2$ = 0.5 x 4.5 x μ x $(6.3)^2$ = 8.9(3) x 10^{-5} (J) / 89.3 μ(J)	**C1** **A1**	Allow use of E = ½ QV and the Q value from **(b)(i)** Q=28 E= 8.82 and Q=28.4 E=8.946 Allow ecf from **(b)(i)** penalise power of ten error (-1)
c	**(i)**	Electrons / they move in an anticlockwise direction Charge on plates decreases / electrons neutralise positive charge p.d. decreases <u>exponentially</u>	**B1** **B1** **B1**	Alternatives for anticlockwise: from / lower plate around the circuit, from / lower plate through the resistor to top plate implied Capacitor discharges / loses charge
	(ii)	(dissipated as heat) in the resistor / wires	**B1**	
d	**(i)**	Total capacitance = 1.5 + 4.5 = 6(.0) (μF)	**A1**	Allow one SF
	(ii)	Original charge on 4.5 μF capacitor is conserved (28.35 μC) V = (28.35 μ) / (1.5 + 4.5) μ = 4.7 (V)	**C1** **A1**	ecf from **(b)(i) and (d)(i)**

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

	(iii)	$\frac{1}{2}\times 4.5^2 \times 150\times 10^{-6}$ and $\frac{1}{2}\times 1.5^2 \times 450\times 10^{-6}$ 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	