19. Capacitance

19.3 Discharging a capacitor

Paper 4

Marking Scheme

Q1.

(a)	• p.d. across capacitor proportional to charge on capacitor • p.d. across capacitor = p.d. across resistor • current in resistor proportional to p.d. across resistor • current in resistor = rate of decrease of charge on capacitor *Any two points, 1 mark each*	**B2**
	charge proportional to current so rate of decrease of current decreases as current decreases (therefore exponential shape)	**B1**
(b)(i)	$R = V / I$ $= 12 / (0.13 \times 10^{-3})$	**C1**
	$= 9.2 \times 10^4\ \Omega$	**A1**
(b)(ii)	correct read-off of at least one pair of values for I and t	**C1**
	attempted read-off of t when $I = 0.048$ mA **or** substitution of a correct pair of values of I and t into $I = 0.13 \exp(-t / \tau)$	**C1**
	$\tau = 4.3$ s	**A1**
(c)	$\tau = RC$	**C1**
	$C = \tau / R = 4.3 / (9.2 \times 10^4)$ $= 4.7 \times 10^{-5}$ F	**A1**

Q2.

(c)(ii)	$8.0 = 12.0 \exp(-0.010 / RC)$	**C1**
	$\ln(8.0 / 12.0) = -0.010 / (R \times 5.7 \times 10^{-4})$	**C1**
	$R = 43\ \Omega$	**A1**

Q3.

(b)(ii)	$V = V_0 \exp(-t / RC)$ **and** $\tau = RC$ **or** $V = V_0 \exp(-t / \tau)$	**C1**
	$3.25 = 5.50 \exp(-0.020 / \tau)$ leading to $\tau = 0.038$ s	**A1**
(b)(iii)	$\tau = RC$	**C1**
	capacitance $= 0.038 / 14000$ $= 2.7 \times 10^{-6}$ F	**A1**

Q4.

(b)(i)	$V = V_0 \exp(-t / RC)$ **and** $\tau = RC$	**C1**
	$V = V_0 \exp(-t / \tau)$ $V_0 = 8.0$ V, and at one time constant, $t = \tau$ $V / 8.0 = \exp(-\tau / \tau)$, so $\ln(V / 8.0) = -1.0$ **or** $-\ln(V / 8.0) = 1.0$	**A1**
(b)(ii)	[t read from graph at $-\ln(V / 8.0) = 1.0$]: $\tau = 3.2$ s	**A1**
(b)(iii)	$\tau = RC$	**C1**
	$R = 3.2 / (5.6 \times 10^{-5})$ $= 5.7 \times 10^4\ \Omega$	**A1**

Q5.

(c)(iii)	$V = 0.90 \times 6.0$ (= 5.4 V) **or** discharge time (for each cycle) = 0.034 s	**C1**
	$V = V_0 \exp(-t / RC)$ $5.4 = 6.0 \exp[-0.034 / (1.2 \times 10^3 \times C)]$	**C1**
	$C = 2.7 \times 10^{-4}$ F	**A1**

Q6.

(c)(iii)	initial p.d. (across 22 μF) $= 12 \times (15 / 22)$ $= 8.2$ V **or** final p.d. across both capacitors $= 6.0 \times (22 / 15)$ $= 8.8$ V	**C1**
	$V = V_0 \exp[-t / (2.7 \times 10^6 \times 15 \times 10^{-6})]$	**C1**
	$6.0 = 8.2 \exp[-t / (2.7 \times 10^6 \times 15 \times 10^{-6})]$ **or** $8.8 = 12 \exp[-t / (2.7 \times 10^6 \times 15 \times 10^{-6})]$ $t = 13$ s	**A1**

Q7.

(a)(ii)	$I_0 = 24 / 5600$ $= 4.3 \times 10^{-3}$ A	**A1**
(a)(iii)	$\tau = RC$	**C1**
	$= 5600 \times 470 \times 10^{-6}$ $= 2.6$ s	**A1**
(a)(iv)	line with negative gradient throughout passing through (0, I_0)	**B1**
	exponential decay curve asymptotic to t-axis	**B1**

Q8.

(a)	• p.d. across resistor = p.d. across capacitor • current (in resistor) proportional to p.d. across it • current causes capacitor to lose charge • charge (on capacitor) proportional to p.d. so p.d. decreases *Any two points, 1 mark each*	**B2**
	rate of change of p.d. decreases as p.d. decreases	**B1**
(b)	Q_0 = 0.90 mC **and** at t = one time constant, $Q = Q_0 \exp(-1)$	**B1**
	at t = one time constant, Q = 0.90 exp (–1) = 0.33 mC	**M1**
	evidence of graph reading: when Q = 0.33 mC, t = 5.5 s	**A1**
	or	
	evidence of two correct sets of readings for Q and t from the graph	**(B1)**
	correct substitution of Q and t values into $Q_2 = Q_1 \exp[(t_1 - t_2) / \tau]$	**(M1)**
	calculation to give τ = 5.5 s	**(A1)**
	or	
	read-off of half-life as 3.75 s	**(B1)**
	use of $Q = Q_0 \exp(-t / \tau)$ to show that τ = half-life / ln 2	**(M1)**
	τ = 3.75 / ln 2 = 5.4 s	**(A1)**
(b)	**or**	
	tangent drawn on Q–t graph and value of Q at exact same time as tangent read from graph	**(M1)**
	gradient of tangent correctly calculated	**(A1)**
	τ = Q / gradient used to correctly calculate a value for τ as 5.5 s	**(A1)**
(c)(ii)	$R = \tau / C$	**C1**
	$= 5.5 / (1.2 \times 10^{-4})$ (= 45 800 Ω) = 46 kΩ	**A1**