Mark Scheme Capacitor Past Paper Questions
Jan 2002—Jan 2010 (old spec)

Q3 Jan 2002

3(a) graph to show:
straight line from origin ✓
end point at 4.5 (V), 9.0 (μF) ✓ (2)

(b)(i) $\Delta W = V\Delta Q$ explained ✓
energy stored or total work done in charging = area under graph or charge × average voltage ✓
energy stored = work done (= ½QV) ✓

(ii) $Q = 2.0 \times 1.5 = 3.0$ (μC) ✓
E (=½ QV) = $\frac{1}{2} \times 3.0 \times 10^{-6} \times 1.5 = 2.25 \times 10^{-6}$ J ✓
[or E = (½CV^2 = $\frac{1}{2} \times 2.0 \times 10^{-6} \times 1.5^2 = 2.25 \times 10^{-6}$ J] (5)

(7)

Q2 Jun 2002

2(a) $Q = CV$ ✓
$(= 4.7 \times 10^{-6} \times 6.0) = 28 \times 10^{-6}$ C or 28 μC ✓ (2)

(b) $E = \frac{1}{2}CV^2$ ✓
$= \frac{1}{2} \times 4.7 \times 10^{-6} \times 2.0^2$ ✓
$= 9.4 \times 10^{-6}$ J ✓
[or $E = \frac{1}{2}QV$ ✓
$= \frac{1}{2} \times 9.4 \times 10^{-6} \times 2.0$ ✓
$= 9.4 \times 10^{-6}$ J ✓] (3)

(c) time constant is time taken for V to fall to $\frac{V_o}{e}$ ✓
∴ V must fall to 2.2 V ✓
time constant = 32 ms ✓
[or draw tangent at $t = 0$ ✓
intercept of tangent on t axis is time constant ✓
accept value 30 - 35 ms ✓]
[or $V = V_0 \exp(-t/RC)$ or $Q = Q_0 \exp(-t/RC)$ ✓
correct substitution ✓
time constant = 32 ms ✓] (3)

(d) time constant = RC ✓

$$R = \frac{32 \times 10^{-3}}{4.7 \times 10^{-6}} = 6800\ \Omega$$ ✓

(allow C.E. for value of time constant from (c)) (2)

(10)

4

Q4 Jan 2004

(a) Q (= CV = 330 × 9.0) = 2970 (μC) ✓
E (= ½QV) = ½ × 2.97 × 10^{-3} × 9.0 = 1.34 × 10^{-2} J ✓
[or E (= ½CV^2) = ½ × 300 × 10^{-6} × 9.0^2 ✓ = 1.34 × 10^{-2} J ✓] (*2*)

(b) time constant (= RC) = 470 × 10^3 × 330 × 10^{-6} = 155 s ✓ (*1*)

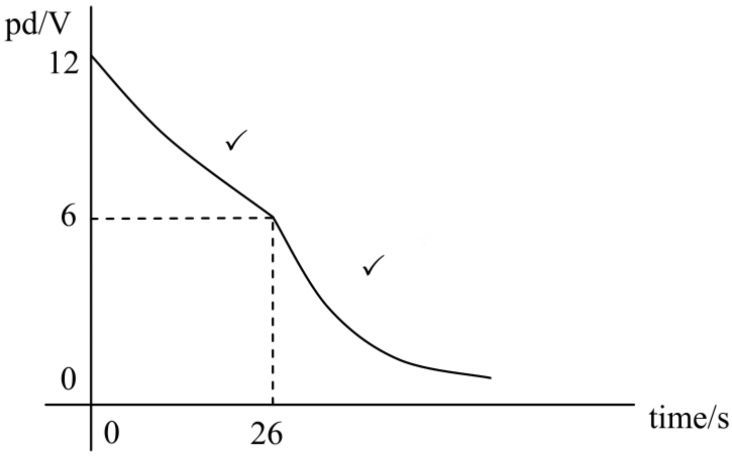
(c) $Q\left(= Q_0 e^{-t/RC}\right) = 2970 \times e^{-60/155}$ ✓
= 2020 (μC) ✓
(allow C.E. for time constant from (b))
$V\left(= \frac{Q}{C}\right) = \frac{2020}{330}$ = 6.11 V ✓
(allow C.E. for Q)
[or $V = V_0 e^{-t/RC}$ ✓ = 9.0 $e^{-60/155}$ ✓ = 6.11 V ✓] (*3*)

(*6*)

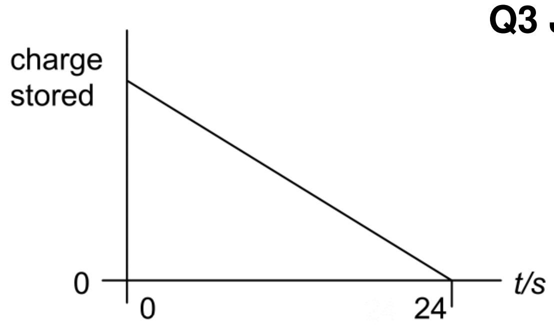
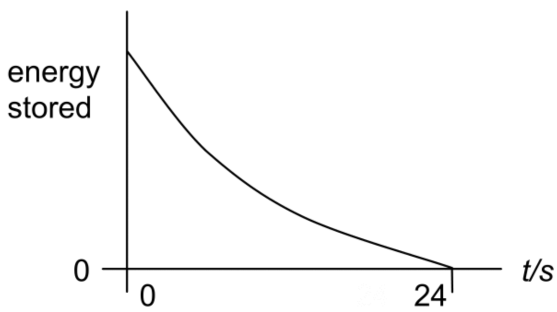
Quality of Written Communication (Q1(a) and Q3(c)) ✓✓ (*2*)

(*2*)

Q3 Jun 2005

Question 3			
(a)	(i)	straight line through origin ✓	
	(ii)	$\frac{1}{\text{capacitance}}$ ✓	**3**
	(iii)	energy (stored by capacitor) ✓ (or work done (in charging capacitor))	
(b)	(i)	$RC = 5.6 \times 10^3 \times 6.8 \times 10^{-3}$ ✓ (= 38.1 s) $V(= V_0\, e^{-t/RC}) = 12\, e^{-26/38.1}$ ✓ = 6.1 V ✓ (6.06 V) [or equivalent using $Q = Q_0\, e^{-t/RC}$ and $Q = CV$]	
	(ii)	$(RC)' = 2.8 \times 10^3 \times 6.8 \times 10^{-3}$ ✓ (= 19.0 s) V (= 6.06 $e^{-14/19}$) = 2.9(0) V ✓ (use of V' = 6.1 V gives V = 2.9(2) V)	**7**
	(iii)		

Question 2		
(a)	$E \propto V^2$ (or $E = {}^1/_2CV^2$) ✓ **Q2 Jan 2006** pd after 25 s = 6 V ✓	**2**
(b) (i)	use of $Q = Q_0\,e^{-t/RC}$ or $V = V_0\,e^{-t/RC}$ ✓ (e.g. $6 = 12\,e^{-25/RC}$) gives $e^{\frac{25}{RC}} = \frac{12}{6}$ and $\frac{25}{RC} = \ln 2$ ✓ (RC = 36(.1) s) [alternatives for (i): $V = 12\,e^{-25/36}$ gives V = 6.0 V ✓ (5.99 V) **or** time for pd to halve is 0.69RC $\therefore RC = \frac{25}{0.69}$ ✓ = 36(.2) s]	**4**
(ii)	$R = \frac{36.1}{680 \times 10^{-6}}$ ✓ $= 5.3(0) \times 10^4\ \Omega$ ✓	
	Total	**6**

Question 3		
(a) (i)	$Q\ (= I\,t) = 35 \times 10^{-6} \times 24 = 8.4 \times 10^{-4}$ C (840 μC) ✓	**2**
(ii)	$C \left(= \frac{Q}{V}\right) = \frac{8.4 \times 10^{-4}}{6.0} = 1.4 \times 10^{-4}$ F (140 μF) ✓	
(b) (i)	line showing charge decreasing as time increases ✓ linear graph meets time axis at 24 s ✓ **Q3 Jan 2007** 	**4**
(ii)	curve of decreasing negative gradient ✓ curve meets time axis at 24 s ✓ 	
	Total	**6**

Question 2		
(a)	appropriate resistor values suggested e.g. 0.5 MΩ to 10 MΩ ✓ **max 2 from** **Q2 Jan 2008** require time constant ≈ overall timing period ✓ suitable overall timing period indicated e.g. 30 s to 5 min **or** suitable value for time constant indicated e.g. 15 s to 5 min ✓ suitable timing interval indicated e.g. 5 s to 20 s ✓ justification by calculation e.g. 60s/30 μF ≈ 2.0 MΩ ✓	3
(b) (i)	$\ln V_0$ = 2.15 ✓ ∴ $V_0 = e^{2.15}$ = 8.6 V ✓	
(ii)	gradient = – $(1/RC)$ ✓ = (-) $\frac{2.15-1.00}{50}$ = (-) 0.0230 (s^{-1}) ✓ time constant = 43(.5) s ✓ [**or** when $t = T$, $V = V_0e^{-1}$ (= *3.16* V) ✓ $\ln V = \ln 3.16$ = 1.15 ✓ from graph, when $\ln V$ = 1.15, T = 43.5 s ✓] [**or** when t = 50 s, $\ln V = V_0 - (t/RC)$ gives 1.00 = 2.15 – (50/RC) ✓ ∴ (50/RC) = 1.15 ✓ and RC = (50/1.15) = 43.5 s ✓]	max 5
(iii)	$C = \frac{43.5}{91\times10^3}$ = 480 (477) μF ✓	
	Total	**8**

Question 3			
(a) (i)	1	(net) electron flow is round circuit (from **Q**) to **P** ✓	max 5
	2	(rate of) electron flow (or current) decreases (as t increases) [or repulsion from electrons already on **P** makes flow decrease] ✓	
	3	electron flow (or current) ceases when pd across **PQ** = emf (or 2.0 V) ✓	
	4	electron flow rate (or current) decreases exponentially ✓	
(ii)	5	pd across capacitor increases ✓ **Q3 Jan 2009**	
	6	pd across resistor decreases ✓	
	7	$V_R + V_C$ = 2.0 V (or = emf) ✓	
	8	V_C increases to 2.0 V and V_R decreases to 0 V ✓	
	9	V_C (or V_R) changes exponentially with time ✓	

(b) (i) (ii)	$E\ (= \frac{1}{2} C V^2) = \frac{1}{2} \times 50 \times 10^{-6} \times 2.0^2$ ✓ $= 1.0 \times 10^{-4}$ J ✓ line drawn as a curve of increasing gradient that starts at (0, 0) ✓ parabolic shape, checked from points on line, which reaches 2.0 V ✓	**4**
	Total	**9**

Question 2		
(a)	$C = \frac{Q}{V}$ ✓ **Q2 Jun 2009** where Q = charge stored by (one plate of) capacitor V = pd across capacitor ✓ [**or** C = charge required to increase pd by 1 V ✓✓]	**2**
(b)	$\Delta W = V\,\Delta Q$ explained ✓ work done (or energy stored) = area under graph (or calculated by reference to mean V) ✓ ∴ energy stored = work done ($= \frac{1}{2} Q V$) ✓	**3**
(c) (i) (ii)	$C\left(=\frac{Q}{V}\right) = \frac{9.0\times10^{-6}}{45}$ ✓ $= 2.0 \times 10^{-7}$ F (0.20 μF) ✓ $E\left(=\frac{Q^2}{2C}\right) = \frac{(3.0\times10^{-6})^2}{2\times2.0\times10^{-7}}$ ✓ $= 2.25 \times 10^{-5}$ J (23 μJ) ✓ [**or** $E\ (= \frac{1}{2} C V^2) = \frac{1}{2} \times 2.0 \times 10^{-7} \times 15^2$ ✓ $= 2.25 \times 10^{-5}$ J ✓ **or** $E\ (= \frac{1}{2} Q V) = \frac{1}{2} \times 3.0 \times 10^{-6} \times 15$ ✓ $= 2.25 \times 10^{-5}$ J ✓]	
	Total	**9**

Question 4		
(a)	electric field strength $E\left(=\frac{V}{d}\right)=\frac{1.90\times10^{5}}{80\times10^{-3}}$ **Q4 Jan 2010** $= 2.4 \times 10^{6}$ V m^{-1} (or N C^{-1}) ✓ (2.38×10^{6})	**1**
(b) (i)	charge on sphere Q (= C V) = $5.6 \times 10^{-13} \times 190 \times 10^{3}$ ✓ $= 1.1 \times 10^{-7}$ C ✓ (0.106 μC) charge is positive ✓	**4**
(ii)	time t between consecutive contacts of sphere on plate P_2 is $t = \frac{1}{420}$ minute $= \frac{60}{420} = \frac{1}{7}$ s ✓ current in microammeter $I = \left(=\frac{Q}{t}\right)=\frac{1.06\times10^{-7}}{(1/7)}$ ✓ $= 7.4 \times 10^{-7}$ A ✓ (0.742 μA)	
(c)	**max 3 from** sphere gains electrons (or is charged –) at P_2 and is repelled by P_2 (or attracted by P_1 or experiences correct force in field) ✓ sphere loses electrons at (or negative charge) P_1 ✓ explanation of return of sphere from P_1 to P_2 ✓ sphere reaches same potential as plate on contact ✓ [accept arguments based on sphere becoming charged + at P_1]	**max 3**
	Total	**10**