

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

- 3(a) graph to show:
 straight line from origin ✓
end point at 4.5 (V), 9.0 (μF) ✓ **Q3 Jan 2002** (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 ($= \frac{1}{2}QV$) ✓

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

(7)

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

Q2 Jun 2002

- (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 $\frac{V_0}{e}$ ✓
 $\therefore V$ 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) $Q (= CV = 330 \times 9.0) = 2970 \text{ } (\mu\text{C}) \checkmark$
 $E (= \frac{1}{2}QV) = \frac{1}{2} \times 2.97 \times 10^{-3} \times 9.0 = 1.34 \times 10^{-2} \text{ J } \checkmark$
 [or $E (= \frac{1}{2}CV^2) = \frac{1}{2} \times 300 \times 10^{-6} \times 9.0^2 \checkmark = 1.34 \times 10^{-2} \text{ J } \checkmark]$ (2)

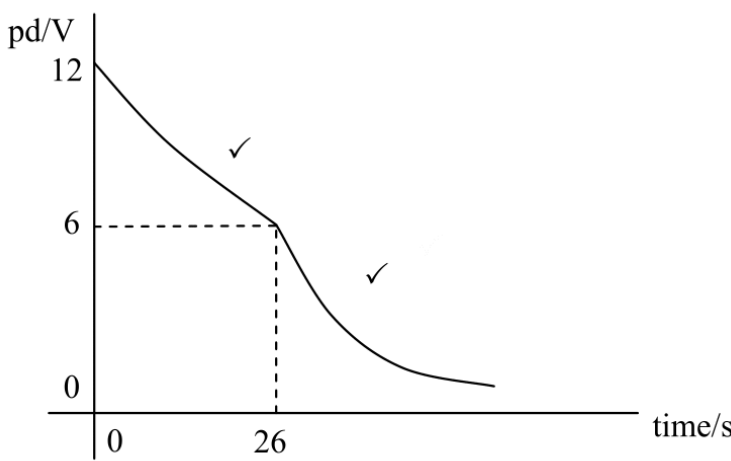
(b) time constant ($= RC) = 470 \times 10^3 \times 330 \times 10^{-6} = 155 \text{ s } \checkmark$ (1)

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

(6)

Quality of Written Communication (Q1(a) and Q3(c)) $\checkmark \checkmark$ (2)

(2)

Question 3		
(a)	(i) straight line through origin \checkmark (ii) $\frac{1}{\text{capacitance}} \checkmark$ (iii) energy (stored by capacitor) \checkmark (or work done (in charging capacitor))	Q3 Jun 2005 3
(b)	(i) $RC = 5.6 \times 10^3 \times 6.8 \times 10^{-3} \checkmark (= 38.1 \text{ s})$ $V (= V_0 e^{-t/RC}) = 12 e^{-26/38.1} \checkmark$ $= 6.1 \text{ V } \checkmark (6.06 \text{ V})$ [or equivalent using $Q = Q_0 e^{-t/RC}$ and $Q = CV$] (ii) $(RC)' = 2.8 \times 10^3 \times 6.8 \times 10^{-3} \checkmark (= 19.0 \text{ s})$ $V (= 6.06 e^{-14/19}) = 2.9(0) \text{ V } \checkmark$ (use of $V' = 6.1 \text{ V}$ gives $V = 2.9(2) \text{ V}$) (iii) 	7

Question 2			
(a)	$E \propto V^2$ (or $E = \frac{1}{2}CV^2$) ✓ pd after 25 s = 6 V ✓	Q2 Jan 2006	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 μ C) ✓		2
(ii)	$C \left(= \frac{Q}{V} \right) = \frac{8.4 \times 10^{-4}}{6.0} = 1.4 \times 10^{-4}$ F (140 μ F) ✓		
(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)	<p>appropriate resistor values suggested e.g. 0.5 MΩ to 10 MΩ ✓</p> <p>max 2 from Q2 Jan 2008</p> <p>require time constant \approx overall timing period ✓</p> <p>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 ✓</p> <p>suitable timing interval indicated e.g. 5 s to 20 s ✓</p> <p>justification by calculation e.g. 60s/30 μF \approx 2.0 MΩ ✓</p>		3
(b)	<p>(i) $\ln V_0 = 2.15$ ✓ $\therefore V_0 = e^{2.15} = 8.6\text{ V}$ ✓</p> <p>(ii) gradient = $-(1/RC)$ ✓ = $(-)\frac{2.15 - 1.00}{50} = (-) 0.0230\text{ (s}^{-1}\text{)}$ ✓</p> <p>time constant = 43(.5) s ✓</p> <p>[or when $t = T$, $V = V_0e^{-1}$ (= 3.16V) ✓</p> <p>$\ln V = \ln 3.16 = 1.15$ ✓</p> <p>from graph, when $\ln V = 1.15$, $T = 43.5\text{ s}$ ✓]</p> <p>[or when $t = 50\text{ s}$, $\ln V = V_0 - (t/RC)$ gives</p> <p style="text-align: center;">$1.00 = 2.15 - (50/RC)$ ✓</p> <p style="text-align: center;">$\therefore (50/RC) = 1.15$ ✓ and $RC = (50/1.15) = 43.5\text{ s}$ ✓]</p> <p>(iii) $C = \frac{43.5}{91 \times 10^3} = 480\text{ (477)}\mu\text{F}$ ✓</p>		max 5
Total			8

Question 3			
(a)	<p>(i)</p> <ol style="list-style-type: none"> 1 (net) electron flow is round circuit (from Q) to P ✓ 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 2.0V) ✓ 4 electron flow rate (or current) decreases exponentially ✓ <p>(ii)</p> <ol style="list-style-type: none"> 5 pd across capacitor increases ✓ 6 pd across resistor decreases ✓ 7 $V_R + V_C = 2.0\text{ V}$ (or = emf) ✓ 8 V_C increases to 2.0V and V_R decreases to 0V ✓ 9 V_C (or V_R) changes exponentially with time ✓ <p style="text-align: right;">Q3 Jan 2009</p>		max 5

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

Question 2			
(a)		$C = \frac{Q}{V} \checkmark$ <p style="text-align: center;">Q2 Jun 2009</p> where Q = charge stored by (one plate of) capacitor V = pd across capacitor \checkmark [or C = charge required to increase pd by 1 V $\checkmark\checkmark$]	2
(b)		$\Delta W = V \Delta Q$ explained \checkmark work done (or energy stored) = area under graph (or calculated by reference to mean V) \checkmark \therefore energy stored = work done (= $\frac{1}{2} Q V$) \checkmark	3
(c)	(i)	$C \left(= \frac{Q}{V} \right) = \frac{9.0 \times 10^{-6}}{45} \checkmark = 2.0 \times 10^{-7} \text{ F } (0.20 \mu\text{F}) \checkmark$	
	(ii)	$E \left(= \frac{Q^2}{2C} \right) = \frac{(3.0 \times 10^{-6})^2}{2 \times 2.0 \times 10^{-7}} \checkmark = 2.25 \times 10^{-5} \text{ J } (23 \mu\text{J}) \checkmark$ $\text{[or } E (= \frac{1}{2} C V^2) = \frac{1}{2} \times 2.0 \times 10^{-7} \times 15^2 \checkmark = 2.25 \times 10^{-5} \text{ J } \checkmark$ $\text{or } E (= \frac{1}{2} Q V) = \frac{1}{2} \times 3.0 \times 10^{-6} \times 15 \checkmark = 2.25 \times 10^{-5} \text{ J } \checkmark]$	
Total			9

Question 4		
(a)	<p style="text-align: right;">Q4 Jan 2010</p> electric field strength $E\left(= \frac{V}{d}\right) = \frac{1.90 \times 10^5}{80 \times 10^{-3}}$ $= 2.4 \times 10^6 \text{ V m}^{-1}$ (or N C^{-1}) ✓ (2.38 × 10 ⁶)	1
(b)	<p>(i) charge on sphere $Q (= C V) = 5.6 \times 10^{-13} \times 190 \times 10^3$ ✓ $= 1.1 \times 10^{-7} \text{ C}$ ✓ (0.106 μC)</p> <p>charge is positive ✓</p> <p>(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 ✓</p> <p>current in microammeter $I = \left(= \frac{Q}{t}\right) = \frac{1.06 \times 10^{-7}}{(1/7)}$ ✓ $= 7.4 \times 10^{-7} \text{ A}$ ✓ (0.742 μA)</p>	4
(c)	<p>max 3 from</p> <p>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) ✓</p> <p>sphere loses electrons at (or negative charge) P_1 ✓</p> <p>explanation of return of sphere from P_1 to P_2 ✓</p> <p>sphere reaches same potential as plate on contact ✓</p> <p>[accept arguments based on sphere becoming charged + at P_1]</p>	max 3
	Total	10