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

3(a)   graph to show:

        straight line from origin ✓

        end <u>point</u> 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 (= ½QV) ✓

  (ii) $Q = 2.0 \times 1.5 = 3.0$ (µC) ✓

$E (= ½ QV) = ½ \times 3.0 \times 10^{-6} \times 1.5 = 2.25 \times 10^{-6}$ J ✓

[or $E = (½CV^2 = ½ \times 2.0 \times 10^{-6} \times 1.5^2 = 2.25 \times 10^{-6}$ J]   (5)

                                                          (<u>7</u>)

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) $E = ½CV^2$ ✓

$= ½ \times 4.7 \times 10^{-6} \times 2.0^2$ ✓

$= 9.4 \times 10^{-6}$ J ✓

[or $E = ½QV$ ✓

$= ½ \times 9.4 \times 10^{-6} \times 2.0$ ✓

$= 9.4 \times 10^{-6}$ J ✓]   (*3*)

(c)   time constant is time taken for V to fall to $\dfrac{V_o}{\mathrm{e}}$ ✓

$\therefore V$ 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 ✓

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

        (allow C.E. for value of time constant from (c))   (<u>2</u>)

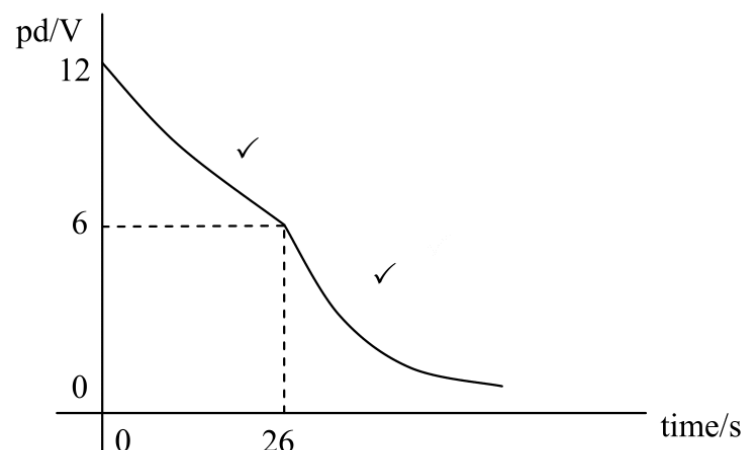   (<u>10</u>)

4

(a) $Q (= CV = 330 \times 9.0) = 2970\,(\mu C)$ ✓   **Q4 Jan 2004**
      $E (= \tfrac{1}{2}QV) = \tfrac{1}{2} \times 2.97 \times 10^{-3} \times 9.0 = 1.34 \times 10^{-2}\,J$ ✓
      [or $E (= \tfrac{1}{2}CV^2) = \tfrac{1}{2} \times 300 \times 10^{-6} \times 9.0^2$ ✓ $= 1.34 \times 10^{-2}\,J$ ✓]   (2)
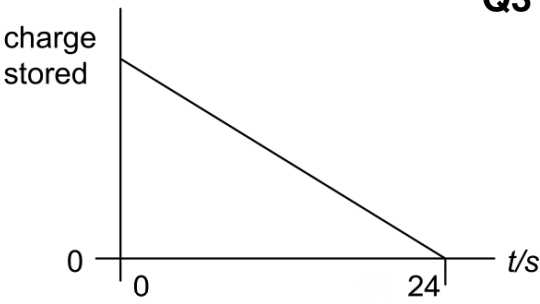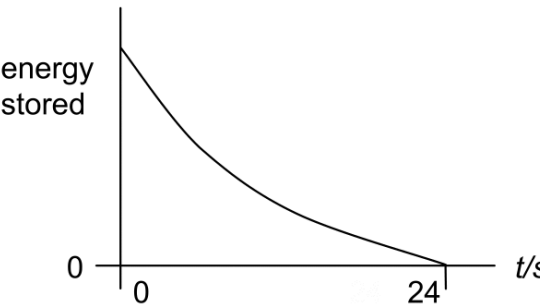
(b)   time constant $(= RC) = 470 \times 10^3 \times 330 \times 10^{-6} = 155\,s$ ✓   (1)

(c) $Q\left(= Q_0 e^{-t/RC}\right) = 2970 \times e^{-60/155}$ ✓
                  $= 2020\,(\mu C)$ ✓
      (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)

Question 3			
(a)	(i)	straight line through origin ✓ **Q3 Jun 2005**	
	(ii)	$\dfrac{1}{\text{capacitance}}$ ✓	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 $E = \frac{1}{2}CV^2$) ✓ 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 $0.69RC$ $\therefore RC = \dfrac{25}{0.69}$ ✓ $= 36(.2)\ s$]		4
	(ii)	$R = \dfrac{36.1}{680 \times 10^{-6}}$ ✓ $= 5.3(0) \times 10^4\ \Omega$ ✓		
			Total	6

Question 3				
(a)	(i)	$Q\ (= I\,t) = 35 \times 10^{-6} \times 24 = 8.4 \times 10^{-4}\ C\ (840\,\mu C)$ ✓		2
	(ii)	$C\left(= \dfrac{Q}{V}\right) = \dfrac{8.4 \times 10^{-4}}{6.0} = 1.4 \times 10^{-4}\ F\ (140\,\mu F)$ ✓		
(b)	(i)	line showing charge decreasing as time increases ✓ linear graph meets time axis at 24 s ✓ **Q3 Jan 2007** charge stored vs t/s graph: straight line from initial value to 24		4
	(ii)	curve of decreasing negative gradient ✓ curve meets time axis at 24 s ✓ energy stored vs t/s graph: decreasing curve to 24		
			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)
	
	 (ii)
	
	 (iii)
		$\ln V_0 = 2.15$ ✓ $\therefore V_0 = e^{2.15} = 8.6 \text{ V}$ ✓
		
		 gradient $= -(1/RC)$ ✓ $= (-) \dfrac{2.15 - 1.00}{50} = (-) \, 0.0230 \, (\text{s}^{-1})$ ✓
		
		 time constant $= 43(.5)$ s ✓
		
		     [**or** when $t = T$, $V = V_0 e^{-1}$ $(= 3.16\text{V})$ ✓
		
		     $\ln V = \ln 3.16 = 1.15$ ✓
		
		     from graph, when $\ln V = 1.15$, $T = 43.5$ s ✓]
		
		     [**or** when $t = 50$ s, $\ln V = V_0 - (t/RC)$ gives
		
		            $1.00 = 2.15 - (50/RC)$ ✓
		
		     $\therefore (50/RC) = 1.15$ ✓ and $RC = (50/1.15) = 43.5$ s ✓]
		
		 $C = \dfrac{43.5}{91 \times 10^3} = 480 \, (477) \, \mu\text{F}$ ✓
			max 5

		Total	**8**

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

(b)	(i)	$E (= \frac{1}{2} C V^2) = \frac{1}{2} \times 50 \times 10^{-6} \times 2.0^2$ ✓ $= 1.0 \times 10^{-4}$ J ✓	4
	(ii)	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 ✓	
		Total	9

Question 2			
(a)		$C = \frac{Q}{V}$ ✓ **Q2 Jun 2009**	2
		where Q = charge stored by (one plate of) capacitor	
		V = pd across capacitor ✓	
		[**or** C = charge required to increase pd by 1 V ✓✓]	
(b)		$\Delta W = V \Delta Q$ explained ✓	3
		work done (or energy stored) = area under graph (or calculated by reference to mean V) ✓	
		∴ energy stored = work done (= $\frac{1}{2} Q V$) ✓	
(c)	(i)	$C \left(= \frac{Q}{V}\right) = \frac{9.0 \times 10^{-6}}{45}$ ✓ $= 2.0 \times 10^{-7}$ F (0.20 µF) ✓	
	(ii)	$E \left(= \frac{Q^2}{2C}\right) = \frac{(3.0 \times 10^{-6})^2}{2 \times 2.0 \times 10^{-7}}$ ✓ $= 2.25 \times 10^{-5}$ 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 $E\left(=\dfrac{V}{d}\right) = \dfrac{1.90 \times 10^5}{80 \times 10^{-3}}$ **Q4 Jan 2010** $= 2.4 \times 10^6 \, \text{V m}^{-1} \text{ (or N C}^{-1}) \checkmark \ (2.38 \times 10^6)$	1
(b)	(i)	charge on sphere $Q \ (= C\,V) = 5.6 \times 10^{-13} \times 190 \times 10^3 \checkmark$ $= 1.1 \times 10^{-7} \, \text{C} \checkmark \ (0.106 \, \mu\text{C})$ charge is positive $\checkmark$	4
	(ii)	time t between consecutive contacts of sphere on plate P_2 is $t = \dfrac{1}{420}$ minute $= \dfrac{60}{420} = \dfrac{1}{7}$ s $\checkmark$ current in microammeter $I = \left(= \dfrac{Q}{t}\right) = \dfrac{1.06 \times 10^{-7}}{(1/7)} \checkmark$ $= 7.4 \times 10^{-7} \, \text{A} \checkmark \ (0.742 \, \mu\text{A})$	
(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) $\checkmark$ sphere loses electrons at (or negative charge) P_1 $\checkmark$ explanation of return of sphere from P_1 to P_2 $\checkmark$ sphere reaches same potential as plate on contact $\checkmark$ [accept arguments based on sphere becoming charged + at P_1]	max 3
		Total	10