Mark schemes

1 (a) $E \propto V^2$ (or $E = {}^1/_2CV^2$) **(1)**

pd after 25 s = 6 V **(1)**

2

(b) (i) use of $Q = Q_0\, e^{-t/RC}$ or $V = V_0\, e^{-t/RC}$ **(1)**

(e.g. $6 = 12e^{-25/RC}$) gives $e\frac{25}{RC} = \frac{12}{6}$ and $\frac{25}{RC}$ = 1n 2 **(1)**

(RC = 36(.1) s)

[alternatives for (i):

$V = 12\, e^{-25/36}$ gives V = 6.0 V **(1)** (5.99 V)

or time for pd to halve is $0.69RC$

$\therefore RC = \frac{25}{0.69}$ **(1)** = 36(.2) s]

(ii) $R = \frac{36.1}{680 \times 10^{-6}}$ **(1)** = 5.3(0) × 10^4 Ω**(1)**

4

[6]

2 (a) (i) straight line through origin **(1)**

(ii) $\frac{1}{\text{capacitance}}$ **(1)**

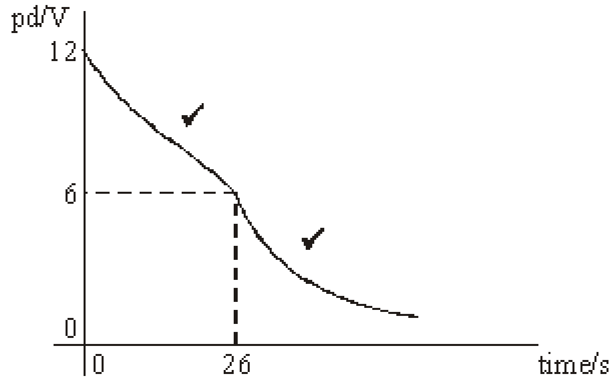
(iii) energy (stored by capacitor) **(1)** (or work done (in charging capacitor))

3

(b) (i) $RC = 5.6 \times 10^3 \times 6.8 \times 10^{-3}$ **(1)** (= 38.1 s)
$V(= V_0\, e^{-t/RC}) = 12\, e^{-26/38.1}$ **(1)**
= 6.1 V **(1)** (6.06 V)
[or equivalent using $Q = Q_0e^{-t/RC}$ and $Q = CV$]

(ii) $(RC)' = 2.8 \times 10^{3} \times 6.8 \times 10^{-3}$ **(1)** (= 19.0 s)
V (= $6.06\, e^{-14/19}$) = 2.9(0) V **(1)**
(use of V = 6.1 V gives V = 2.9(2) V)

(iii)



7

[10]

3 (a) Q (= CV = 330 × 9.0) = 2970 (μC) **(1)**
E (= ½QV) = ½ x 2.97 × 10^{-3} × 9.0 = 1.34 × 10^{-2}J **(1)**
[or E (= ½CV^2) = ½ × 300 × 10^{-6} × 9.0^2 **(1)** = 1.34 × 10^{-2}J **(1)**]

2

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

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))

$V = \left(\frac{Q}{C}\right) = \frac{2020}{330} = 6.11\,V$ **(1)**

(allow C.E. for Q)

[or $V = V_0 e^{-t/RC}$ **(1)** = 9.0 $e^{-60/155}$ **(1)** = 6.11 V **(1)**]

3

[6]

4 (a) $Q = CV$ **(1)**
(= 4.7 × 10^{-6} × 6.0) = 28 × 10^{-6} C or 28 μC **(1)**

2

(b) E = ½CV^2 **(1)**
= ½ × 4.7 × 10^{-6} × 2.0^2 **(1)**
= 9.4 × 10^{-6} J **(1)**
[or E = ½QV **(1)**
= ½ × 9.4 × 10^{-6} × 2.0 **(1)**
= 9.4 × 10^{-6} J **(1)**]

3

(c) time constant is time taken for V to fall to $\frac{V_0}{e}$ **(1)**

$\therefore V$ must fall to 2.2 V **(1)**
time constant = 32 ms **(1)**
[or draw tangent at t = 0 **(1)**
intercept of tangent on t axis is time constant **(1)**
accept value 30 - 35 ms **(1)**]
[or $V = V_0 \exp(-t / RC)$ or $Q = Q_0 \exp(-t / RC)$ **(1)**

correct substitution **(1)**
time constant = 32 ms **(1)**]

3

(d) time constant = RC **(1)**

$R = \frac{32 \times 10^{-3}}{4.7 \times 10^{-3}}$ = 6800 Ω **(1)**

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

2

[10]

5 (a) graph to show:
straight line from origin **(1)**
end point at 4.5 (V), 9.0 (μF) **(1)**

2

(b) (i) $\Delta W = V \Delta Q$ explained **(1)**
energy stored or total work done in charging = area under graph or charge × average voltage **(1)**

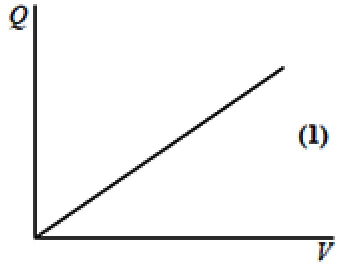
energy stored = work done (= ½QV) **(1)**

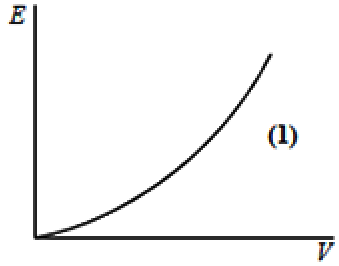
(ii) Q = 2.0 × 1.5 = 3.0 (μC) **(1)**
E (=½ QV) = ½ × 3.0 × 10^{-6} × 1.5 = 2.25 × 10^{-6}J **(1)**
[or E = (½CV^2 = ½ × 2.0 × 10^{-6} × 1.5^2 = 2.25 × 10^{-6} J]

5

[7]

6 (a)





capacitance [or charge per volt or Q/V] **(1)**

(3)

(b) (i) $Q = CV$ (= 0.68 × 6.0) = 4.1 C **(1)**

(ii) $E\left(=\frac{1}{2}QV = \frac{1}{2} \times 4.1 \times 6.0\right)$ = 12 J **(1)**

(2)

[5]

7 D

[1]

8 C

[1]

9 B

[1]

10 D

[1]

Examiner reports

1 Candidates with a sound knowledge of capacitors and capacitor discharge had little difficulty in gaining all six marks. However, it did seem that some centres had not been able to cover these areas fully (if at all) in time for the January examination; candidates from such centres were frequently unable to make anything of the complete question.

Almost inevitably, misunderstanding of E = ² QV in part (a) led many candidates to believe that the pd at 25 s would be 3 V. These candidates were then unable to arrive at a time of 36 s for the time constant in part (b), but could still access both marks in part (b) (ii). Many excellent responses were seen in part (b) (i), where familiarity with logarithmic solutions to exponential relationships was almost essential. Examiners gave no credit in part (a) to those candidates who attempted an exponential solution by using the 36 s given in part (b); a successful solution had to come from the energy information. Similarly, only one of the two marks in part (b) (i) was available for those who turned the question on its head by showing that V would be 6 V after 25 s, if the time constant were 36 s.

2 This question was often well answered, with marks of 9 or 10 frequently being awarded. Part (a) (ii) proved troublesome for most. Although almost all candidates recognised that $V = Q/C$ would lead to a straight line through the origin, relatively few were sufficiently alert to spot that the gradient was $1/C$; a far more popular choice was C. Most knew that the area represented energy (or work done).

In part (b), the two resistors in parallel posed a problem for some, but there were many correct solutions to (b) (i). The principal errors in (b) (ii) were to take the wrong resistance value (11.2 kΩ instead of 2.8 kΩ), or to use the wrong time (40 s instead of 14 s), or both. The sketch graphs in (b) (iii) were often drawn well, even by some candidates who had not been successful with the previous calculations. Examiners were expecting the exponential decay curve to start at $t = 0$ and to become steeper after a discontinuity at $t = 26$ s. Some candidates drew a linear decay graph, whilst others showed an exponential curve passing continuously through $t = 26$s.

3 The mathematical competence of the majority of candidates in this question was much better than has been seen in several recent papers and full marks were frequently awarded. Previous reports have emphasised that ½ CV^2 is a safer route to the energy of a capacitor than ½ QV, and in part (a) the message appeared to have got through to the candidates. In part (b) the main problems appeared to be with the meaning of micro in μF and of kilo in kΩ; the unit of time constant was expected to be shown as s and not ΩF.

The exponential decay equation was usually used correctly in part (c), where approaches via $Q = Q_0\ e^{-t/RC}$ and $V = V_0\ e^{-t/RC}$ were equally valid. Only a tiny minority of the candidates attempted any other approach and almost all of them were wrong.

4 It was satisfying to see so many excellent answers to a question on a subject area that has caused problems in the recent past, and also on those sections testing parts of the specification dealing with the mathematics of exponential discharge, which have been re-introduced at A level. Part (a) only seemed to trouble those candidates who had not learnt $Q = CV$, together with those who did not know that 1 μF = 10^{-6} F. When finding the stored energy in part (b), many more candidates realised that $E = ½CV^2$ is a safer approach than $E = ½QV$, but the latter equation also provided a large number of correct answers.

Three alternative routes were possible when answering part (c). Most candidates preferred to start from the exponential decay equation (either in terms of V or in terms of Q), substituted values, took logs and proceeded to a solution. It was pleasing that so many succeeded. The most elegant solutions came from the candidates who knew that the charge stored falls to (1 / e) of the initial charge in a time equal to the time constant. Solutions that made use of the gradient of the initial section of the graph were exceedingly rare. Part (d) was usually well rewarded in most scripts, with candidates working from their knowledge of the time constant as RC.

5 More careful reading of the question would have produced a greater number of satisfactory answers to the sketch graph in part (a). Most candidates realised that a straight line from the origin was needed, but many lines were continued beyond the point 4.5 V, 9.0 μC. Almost inevitably, some of the lines were drawn as exponential curves.

'Derivation of' seems to be an unwelcome term in the new Specification, for very few candidates were able to produce a completely satisfactory answer to part (b)(i), which required them to show that $E = ½QV$. Whilst most candidates could identify energy stored with the area under the graph, only a tiny minority could link energy stored with work done by the charging source, or explain $\Delta W = VQ$. Consequently it was usual to award only one mark out of the three available for part (i). Answers to part (b)(ii) were usually correct with many candidates sensibly choosing to approach the calculation via $½CV^2$.

6 Most candidates answered this question well and full marks were not unusual. As mentioned in the introduction, some candidates were very careless in drawing their sketch graphs. It was sometimes not clear whether the candidate intended the first graph to be a straight line. The calculations did not cause many problems, although some candidates did pick up a significant figure penalty here.

Part (c)(ii) required a descriptive answer and caused problems. Even though most candidates did get the idea, they found it difficult to express themselves in a clear and concise way. A minority did not really understand the question and discussed a capacitor charging circuit or became very confused discussing how the resistance of the lamp filament changes with temperature.

7 Capacitors were the topic tested by this question. The question needed knowledge of how to apply $Q = I\,t$ for a constant current, $C = Q / V$ and energy stored = ½ CV^2. Three quarters of the candidates succeeded.

8 The Capacitors were the topic tested by this question which needed knowledge of how to apply Q = I t for a constant current, C = Q/V and energy stored = ½ CV2.

9 The connection between the pd applied across a capacitor and the energy it stores was the subject of this question Almost three-quarters of the students were able to see that a 100:1 capacitance ratio would imply a 1:100 ratio for V^2 if the energy was to be the same.The students in 2012 found.

10 This question to be rather more demanding than those who faced this question when it appeared in a previous test, thus causing the facility to decrease from 69% to 64%. Students who were successful here had to understand the meaning and significance of the time constant of an *RC* circuit, and in particular that the pd would decrease to 1/e of its initial value after a time equal to one time constant.